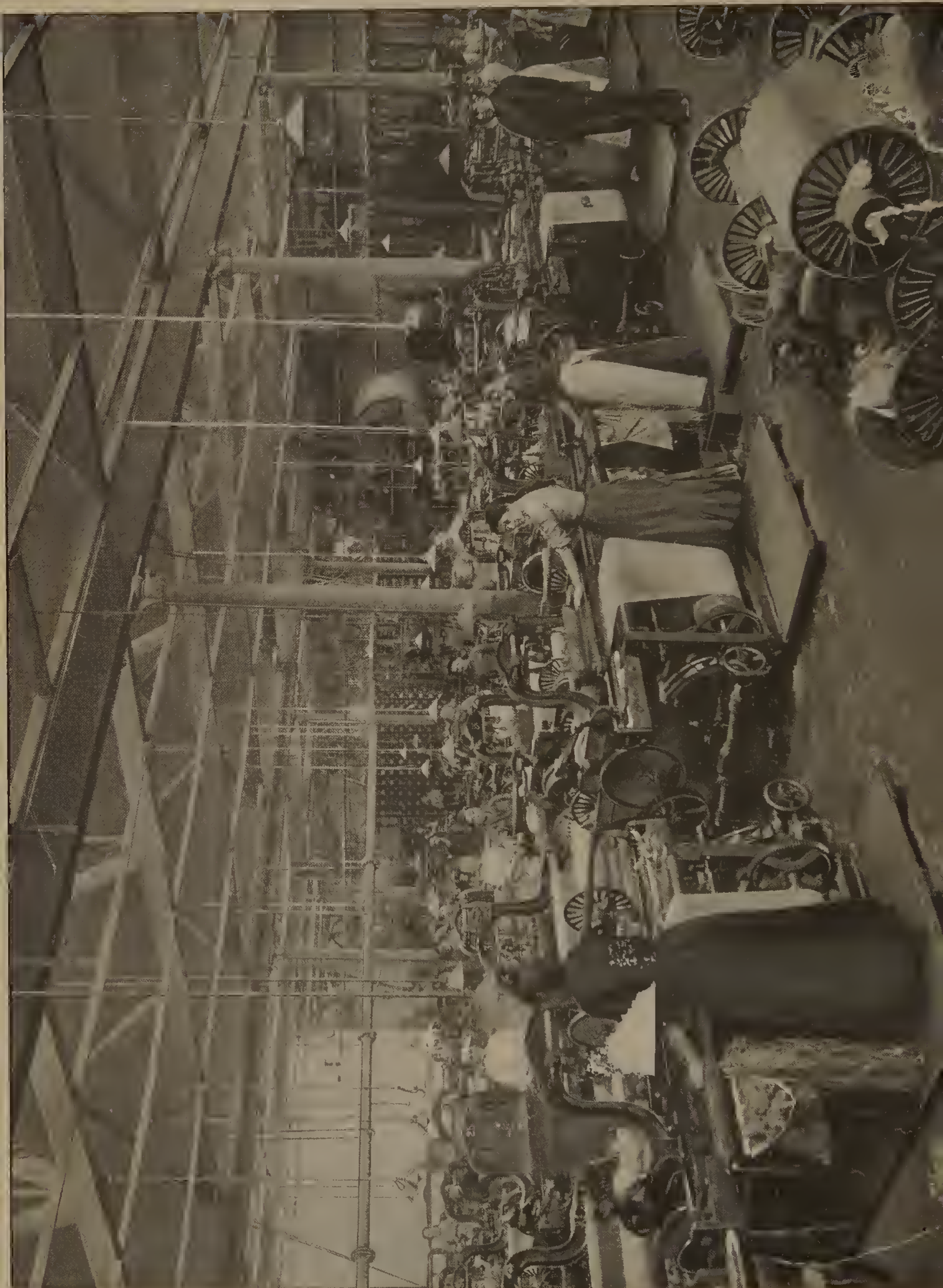

Frontispiece. *Manufacture of Linen, Hemp and Jute Fabrics.*

THE MANUFACTURE OF LINEN, HEMP, AND JUTE FABRICS

COMPILED BY

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"*Modern Flax, Hemp, and Jute Spinning and Twisting*," "*Rope, Twine, and Thread Making*," "*Cordage Fibres*," *&c.*

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PREFACE.

In compiling this volume we are merely bringing together in book form a series of articles which has been appearing from month to month in our *Jute, Hemp and Flax Trades' Journal.* In doing so we hope that we have produced a useful text-book for the use of technical students, apprentices, and others engaged in the industries concerned.

THE PUBLISHERS.

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THE MANUFACTURE OF LINEN, HEMP AND JUTE FABRICS.

CHAPTER I.

HISTORY OF THE INDUSTRY.

FLAX was probably the first textile fibre of vegetable origin to be spun and woven into cloth. As early as 200 B.C. Egypt was famed for its linen fabrics, which were eagerly purchased by foreign nations. Many examples of their art have come down to us in the form of mummy cloth, some of them being wonderfully fine. A sample preserved in the British Museum, for instance, has no less than 152 warp threads per inch, and 71 shots of weft.

Pliny tells us that towards the end of the first century hemp was in common use among the Romans for sails. Indeed, the English word canvas owes its origin to the Latin *cannabis*, or hemp, showing that the fabric was originally made of hemp.

Herodotus describes the hempen garments made by the Thracians as equal to linen in fineness, Hesychius says that the Thracian women made sheets of hemp. Hempen cloth became common in Central and Southern Europe in the thirteenth century.

The birth of the jute-weaving industry is comparatively recent. It may be said to date from 1830, when the jute fibre was first brought to the notice of English and Scotch manufacturers.

The hemp-weaving industry as such can hardly be said to exist to-day, being for all practical purposes merged in the linen industry, in the coarse end of which hemp yarns are used to some extent, either alone or in combination with linen

yarns. In the carpet trade hempen warps are used with woollen wefts and *vice versa*.

The chief seats of the linen industry are Belfast, Dunfermline, Barnsley, Dundee, Arbroath, Kirkcaldy, Forfar, Cupar, Ghent, Roulers, Courtrai, Lille, Armentières, Amiens, Cambrai, Epinal, Bielefeld, Richenburg, Sorau, and Trautenau.

Some of the finest linen fabrics produced are woven in Lurgan, in the Cambresis and in the Vosges. Dundee, Arbroath, Armentières and Barnsley produce the coarse cloths, while the others produce those of medium fineness.

Jute weaving is almost wholly carried on in Dundee and Calcutta. The goods produced comprise Dutch twill carpets, rugs, squares and mattings, Venetians, stars, fancy twills and figured carpets, upholstery cloths, printing cloths, hessians, bagging, tarpaulin cloth and sacking.

The chief makes of linen fabrics are scrims, nettings, lawns, cambrics, linens, hollands, crashes, interlinings, dowlas, Russian sheeting, ducks, canvas and sail-cloth.

Ancient Egyptian drawings show us that more than twenty centuries ago the loom in use consisted of an upright frame in which the threads of warp were stretched. The weft was put in by hand with the aid of a long needle, and pressed down with the latter upon the preceding shot.

The modern loom consists of a framework over which the warped threads are stretched horizontally from the yarn beam to the cloth beam. The weft is carried in the shuttle which is thrown across among the warp threads, while the weft is beaten up against the preceding shot by the slay which carries the reed.

CHAPTER II.

PREPARING THE WARP.

THE first operation in weaving is the preparation of the warps for the loom. If the factory is in connection with a spinning mill, the warp yarn may be received direct from the spinning frame in the form of ring-spun cops or upon ring or flyer frame bobbins. In whichever form it is received it is usually first wound either upon large warper's spools, upon a machine such as is shown in fig. 1, which is a warp winding machine to wind from spinning frame bobbins, or into the form of rolls or cheeses upon a roll-winding machine to wind from spinning bobbins. In machines of this sort the spool or roll is driven by friction against the fluted spool drivers, against which they are pressed by means of levers and weights. The rolls are formed upon a wooden or paper tube, and are stopped automatically, when the required diameter is attained, by means of an arrangement of levers which raise them out of contact with their drivers. The rate of winding is uniform on machines of this description, being independent of the diameter of the spool or roll, since the latter are driven by frictional contact with their drivers, which have a constant angular velocity. It will be seen from the figure that the tension of the thread is kept fairly uniform by means of spring pressers which bear against the surface of the yarn upon the spinning bobbin. They press most forcibly at the right time, *i.e.*, when the bobbin is full or when the yarn is being drawn off the circumference of a larger circle, and when it consequently has a greater purchase. The speed of the thread guide for spool winding is comparatively slow, while for roll winding it re-

quires to be quick in order to build a firm cheese which will not ravel at the ends. Although some space is lost by the crossing of the yarn upon a cheese, yet on account of the space occupied by the flanges of a warper's spool a cheese of like bulk will contain a greater length of yarn. Cheeses are often built to weigh as much as 8 lb.

In dealing with wet spun yarns, coming direct from the spinning room, the spinning frame bobbins must be unwound upon an upright spindle winding frame, on to tin warper's spools, which are afterwards dried in the stove or hot room. What is known as a split drum winder is also used in warp

FIG. 1.

Warp Winding Machine.
Ketten-Spulmaschine
Разматывальная Машина.

winding, the quick traverse for cheese building being produced by the friction drum itself, which is split, or in two halves, forming a cam-shaped split in which the thread travels.

If the warp yarn has been reeled by the spinner and sold to the weaver in hanks or bundles, or if it has been reeled for bleaching, boiling or dyeing, it must be warp wound upon a hank winding frame such as is shown in fig. 2. Hank warp winding frames are usually drum or split drum winders, and provided with as many "swifts" or "flies" as there are drums. "Swifts" are the light wooden frameworks seen in the figure, which extend and carry the hank. They turn upon a central axle which rests upon supports at either side, and should

FIG. 2.—Hank Warp Winder.

revolve quite freely as the yarn is pulled from them. A small drag or break hangs from their centre, so that they may not overrun themselves when an end breaks, and so that an even tension may be kept upon the ends. Great care must be taken to place the hank straight and evenly upon the fly, otherwise great difficulty will be experienced in winding fine and weak yarn. The first end is easily found, being tied up in the leasing of the hank, if the reeler has done her work properly.

Having wound the warp yarn upon large spools or into large cheeses, the next process consists in warping, so as to prepare a series of threads of sufficient number to form a web of the desired length and width when laid in parallel order at the required distance apart, according to the fineness of the cloth which it is desired to produce.

The gauge by which the spacing of the warp thread is regulated is called a reed. It consists of a series of thin flat wires set on edge, equally spaced and joined together top and bottom. In the loom the warp threads pass, one or more at a time, through the spaces between the wires, unless otherwise stated, it being understood that two threads pass through each space, split, or dent of the reed.

The fineness of the reed as used in the Irish linen trade is calculated according to the number of hundreds of splits upon 40 in., that number being the sett of the cloth regardless of width. Two threads are taken into each split of the reed. Thus a 12^{00} linen fabric has 2,400 threads in 40 in. of the reed.

In the Scotch trade the porter system of indicating reeds is that generally used. This system shows the number of porters of 20 dents each, which there are in 37 in. In some handloom districts the reeds are set on 36 in. For drills the setting is different. They are calculated by the number of Irish beers or Scotch porters of 20 splits or 40 threads that there are in 30 in. of the reed. Thus a 50-beer drill would have 50 beers or porters of warp = 2,000 threads on 30 in. This may be easily reduced to Irish linen setting by adding one-third the

number of threads and then dividing by two. Damasks are usually counted by the porters or beers in the usual width of the particular make of cloth. For instance, 80-beer 3/4 or 27 in. wide and 80-beer 8/4 or 72 in. wide would be called 80-beer damask, but would vary in fineness in proportion to their widths. The simplest way is to reduce all these varying standards to the common basis of threads per inch for comparison.

The counts of reed which are suitable far various yarns depend upon the diameter of those yarns. When the diameter of one thread is known, the diameter of another will vary as the square root of the counts, for the counts of yarn differ as the squares of their diameters.

All cloths shrink or contract somewhat in the width of the reed while being woven. As this contraction amounts to about $7\frac{1}{2}$ per cent., the number of threads necessary to make 37-in. cloth of the desired fineness must be spread over a 40-in. reed.

From these details, the number of ends of warp required to form a cloth of given width and fineness may be calculated. Thus a 14^{00} 36 in. lawn will have $\frac{1400 \times 2 \times 36}{40} = 2{,}520$ ends of warp. A 11 porter 40 in. Hessian $\frac{11 \times 40 \times 40}{37} = 476$ ends. A 60 beer 36 in. drill would have $\frac{60 \times 40 \times 36}{30} = 2{,}880$ ends of warp, and so on.

These ends must be drawn from the warper's spools, cheeses, or rolls which have been prepared for the purpose, and eventually brought together upon the weaver's beam. In order to be unwound, the warper's spools or cheeses must be placed upon spindles in the warper's creel or bank. Since it is quite impossible for the warper to attend to a creel bearing such a large number of bobbins as 2,520, for instance, it is usual to run one-fourth, one-sixth, or one-eighth of the number of ends required for the web upon each warper's beam, and then to combine four, six, or eight of these warper's beams, running

FIG. 3.—Warping Mill.

them together upon the weaver's beam in the beaming machine or the dressing machine.

Warps for hand looms are generally formed upon a warping mill, such as is shown in fig. 3. As the bank or bobbin creel shown carries a maximum of 60 spools, the number of ends of warp required must be divided into a convenient number of bouts. Thus, to form a chain or warp upon the warping mill, having, in all, the 476 ends required by an 11 porter 40 in. Hessian—seven bouts of 60 spools and one bout of 56 spools may be run upon the mill.

The circumference of the mill is usually from 10 to 13 yards. It may have 24, 26, 28 or 30 spokes. Its height is from 6 ft. to 7 ft. 6 in., giving a working space about 1 ft. less.

The warper first fills his creel with spools, and then, drawing the ends from each in regular order, he draws them through the eyes of the "hake" or guide reeds which are fixed in the hake box. There are two guide reeds in the box, alternate threads passing through each, and both being movable vertically, the yarn may be divided equally when it is desired to form the lease.

The mill is turned in either direction by a hand wheel, pulley and band, passing round the periphery of the mill at the bottom. The hake box is raised and lowered, as the mill is turned in one direction or the other by means of a worm upon the central axis of the mill, driving a worm pinion upon a horizontal overhead shaft carrying a sprocket wheel upon the extremity over the hake box. A chain attached to the hake box passes over this wheel, and in this way the hake is raised and lowered so that the yarn may be lapped around the mill in spirals.

In an older form of mill the hake box is suspended by a cord fixed at one end, and passing round four pulleys to the axis of the mill, around which it is lapped. The travel of the box is consequently only one-fourth that of the length of cord

wound upon the central axis. The diameter of this latter is about 2 in., so that the pitch of the spiral laps is $\frac{2 \times 3 \cdot 1416}{4}$ $= 1\frac{1}{2}$ in.

Supposing that a chain or warp 650 yards in length is to be keeled or marked for 5 cuts upon a 13-yard mill—then $\frac{650}{13} = 50$ rounds of the mill will be required.

The warper begins with the hake box at the top of its course. He knots the ends together which he has drawn through the guide reeds, divides the yarn equally by means of the hake, and passes the yarn thus divided over the first and second of the three forks. Again dividing the yarn by means of the hake, he passes the yarn over the third fork, thus forming the "thread by thread," or drawer's lease.

He then proceeds to make the fifty turns of the mill required to warp the 650 yards which it is desired to produce, taking great care that no ends break or spools run out while so occupied. When the required number of turns of the mill have been given, the lower forks, also seen in the plan, are inserted, and the warper proceeds to form the "pin" or beamer's lease. This he does by counting off the threads in the guide reed, or dividing the total number of threads in the bout into a convenient number of parts which he passes alternately under and over the first and second of the lower forks, and repeating the operation while turning the mill back in the opposite direction. When the upper forks are reached, the drawer's lease is formed as before, and then again once more before running down for number three bout. At the same time the hake is "tempered" or lowered about $\frac{1}{2}$ in., so that the spirals of yarn may not be built one on top of the other. This is usually done by letting out one tooth of a ratchet wheel provided for the purpose. The process is repeated in the case in question until seven bouts are complete, when four ends are broken down from one edge of the hake and an eighth bout put on, thus forming a chain of 476 ends. While the last bout is being put on, the warper should mark or keel the

yarn at the proper points for cutting when woven, by counting off the proper number of rounds, in this case ten for five cuts. When finished, the yarn is cut and the ends tied round the first fork as at the beginning. In order that both the drawer's and the beamer's lease may be preserved, bands are passed between the threads at the forks and firmly tied. Then the warper lifts the yarn off the first fork and proceeds to draw it away, linking it into a chain while so doing. If he knots the ends hanging from the hake, divides the yarn and forms a drawer's lease around the top forks, he may start a second chain while linking up the first. If a very large number of ends are required in the chain, the mill may become over-loaded before a sufficient number of bouts have been warped. In that case it is better to form two or more chains, which may be afterwards run together in the beaming process.

In the factory, the yarn to be used for warp is usually drawn directly from the warper's bobbins or cheeses, which revolve in the V-shaped "bank," and is wound in regular and parallel order upon the warper's beam which revolves in the warping machine. As before explained, one-half, one-fourth, one-sixth, or one-eighth the total ends of warp required for the web are placed upon each warper's beam, two, four, six, or eight such beams being combined together in the beaming or dressing machine and run together upon the weaver's beam.

It is in the warping process that the cotton or coloured ends required to form selvedges and stripes are introduced in the proper place and in suitable numbers. The selvedges are, of course, the edges of the cloth. Since the selvedge threads have to bear more strain than the other threads of the warp, owing to the pull of the weft, they are often of cotton yarn, as being stronger and more elastic. Stripes are often introduced, especially as bordering in such goods as roller towellings, glass cloths, &c. Navy canvas for the United States Government has a blue stripe from $1\frac{1}{8}$ to $1\frac{7}{8}$ in. from either edge, according to the quality of the canvas.

The number of bobbins of selvedge yarn or coloured yarn for stripes which must be placed in the creel or bank depends, of course, on the width of the stripe, the number of splits per inch in the reed to be used, and the number of ends which it is intended to pass through each split.

In order that the threads which are to form the warp of the cloth may be placed in such a manner that they can easily, and without mistake, be placed in convenient order in the loom, they should pass alternately over and under the two lease rods of the warping machine, so that the first and all the odd-numbered threads pass over the first lease rod and under the second, while the second thread and all the threads of even number pass on the contrary under the first and over the second lease rod. This part of the warp which is so arranged is called the "lease," and serves the purpose of enabling the drawer-in to find each thread in the order in which he requires it to pass through the heddle eyes and through the reed of the loom.

Warping requires a great deal of attention. The warper should not only watch that no threads are missing, but also that the lease is well made, and also that the threads are kept at an equal tension.

Chain beaming follows chain warping, as described on p. 10. The ends of the chain containing the beamers or chain lease are passed round a set of three rollers or tension bars set about 16 feet behind the beaming machine. By means of the pin lease, the beamer spreads the warp over the swinging and fixed "raddles" to the width of the beam, which should be a few inches more than the warp is to occupy in the reed of the loom. After passing through the fixed raddle or evener, the ends are attached to the loom beam, upon which they are wound at a suitable speed, being firmly and solidly built by means of a pressing roller. Two speeds are given to the beaming machine by means of an arrangement, consisting of two fast and one loose pulley, combined with gearing suitably arranged.

If the warp which has been prepared upon the beam warping machine does not require dressing, it is beamed from the warper's to the weaver's beams upon a beaming machine, in which the warper's beams, one, two, three, or four in number, are placed in support at either end of the machine, and the yarn drawn through a guide reed, passed over tension bars and rollers, and on to the beam in front, upon which it is tightly lapped by means of a pressing roller. This pressing roller rises as the beam fills, and may also be lifted when required by means of a hand wheel, gearing, and rack.

The sizing or dressing of warp yarns is a very general practice for fabrics of every description. It has as its objects the laying of any loose fibres on the surface of the thread, the production of a harder surface on the thread, so that it may not be frayed by the friction of the loom, and the most important of all, the giving of increased strength to the thread, so that fewer breakages may be produced or inferior yarn used.

For hand-loom work the warp is dressed after it is put into the loom, stretches of a yard or so being dressed at once, and then woven up. The usual hand-loom weavers' dressing is flour paste made of the best flour. It should be made sufficiently thick to form a nice jelly when cool. When being used by the hand-loom weaver, it is applied with two brushes. The warp, tightened up, with the heddles drawn forward and the lease rods backward, is brushed lightly and evenly both above and below, till the dressing is spread over it in sufficient quantity. When this has been done it is dried with a fan.

For power-loom work the warp is dressed as it is being transferred from a set of warper's beams to the weaver's beam. There are two styles of dressing machines used, *i.e.*, the cylinder machine and the crank machine. The latter machine is illustrated in fig. 4, and is made to imitate the work of the hand-loom weaver in dressing his warp. There are supports for the warper's beams at either end of the

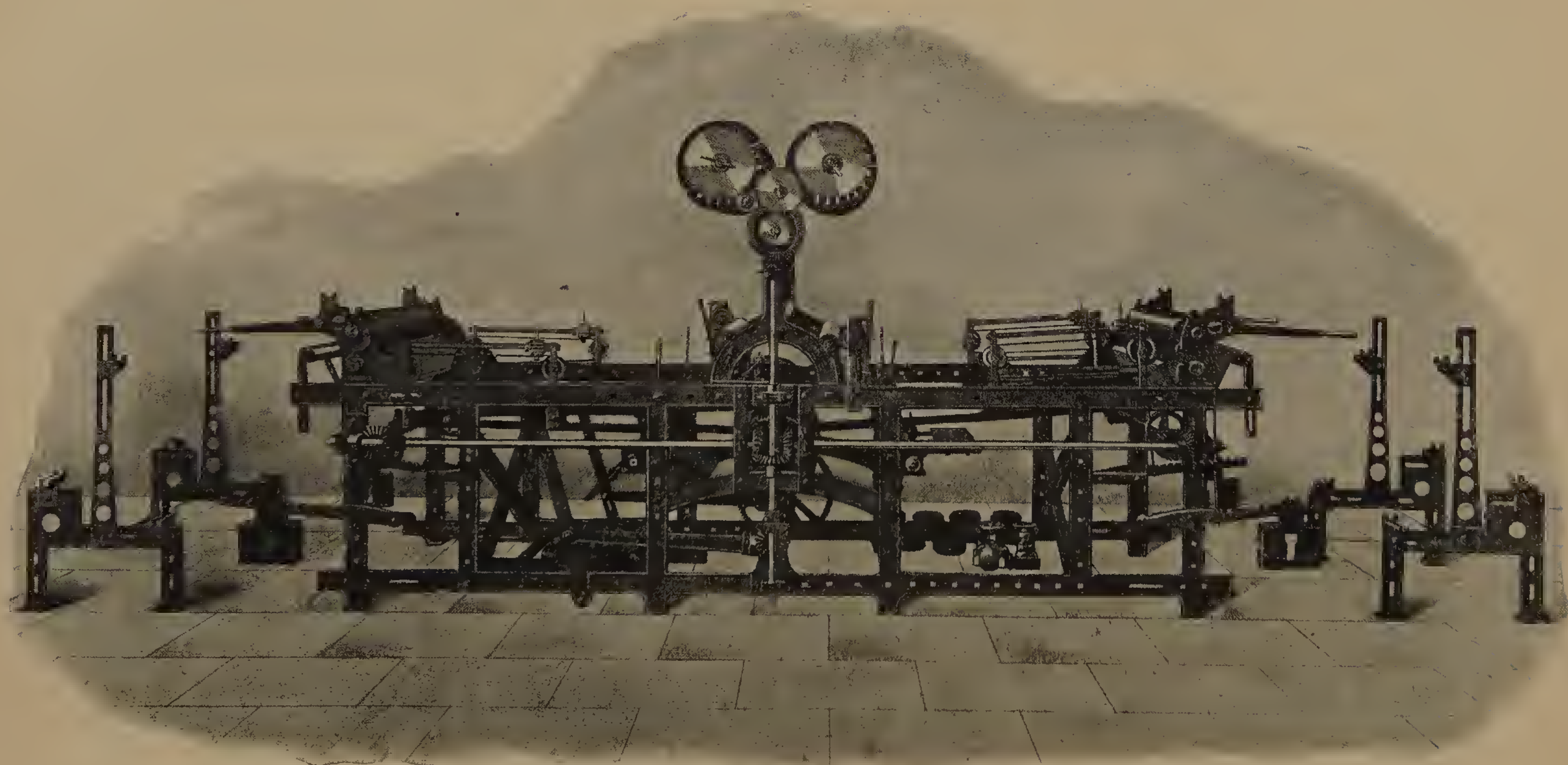
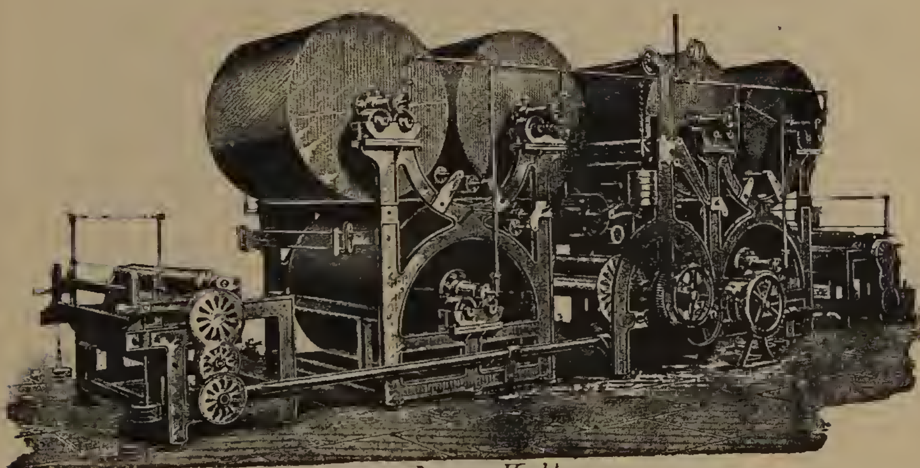


FIG. 4.—Crank Dressing Machine.

machine as well as starch box and roller, squeezing roller and a pair of brushes. The yarn is dried as it passes to the loom beam by means of fans, seen in the illustration, which send the air, which is heated by a set of wrought-iron heating pipes, through it.

Heavy jute yarns are sometimes dried, after the dressing has been applied, by passing them round a series of two or three steam-heated drying cylinders, of large diameter (as seen in fig. 5), before they reach the winding-on beam.

FIG. 5.



Yarn Dressing Machine.
Garn-Schlicht-Maschine.
Шлихтовальная Машина.

Occasionally the yarn is merely damped and then dried in this way before weaving, with the object of smoothing it.

The cylinder machine, which is the one most used for linen yarns, takes its name from the cylindrical brushes, which revolve and brush the yarn as it passes over them. It may be briefly described as follows: The warper's beams, to the number of 2, 3, or 4, rest upon their supports at either end of the machine. The yarn is drawn off them, passes through a reed, over a supporting roller, and through the nip of the dressing rollers. These rollers are of metal, the lower one which revolves in the dressing trough being covered with

calico, and the upper one flannel-covered, its duty being to squeeze out the surplus dressing. Leaving the dressing trough, the yarn next passes under a roller, which keeps it down upon the revolving brush, turning against the course of the yarn, which helps to lay the fibre and level the dressing. Underneath this brush is another smaller one, which turns in a trough of water to keep the large one clean. The yarn next passes through another reed, and over and under three lease rods, the back one dividing the yarn in half, and the other two dividing each of these halves. Underneath these lease rods is a steam chest, containing a quick running fan, which forces the hot air through the yarn to dry it. The threads then pass through the dents of two more reeds, between which is a rod dividing the warp in half, and are then operated upon when required by a tallow brush, which revolves, and is supplied with tallow by a tallow roller turning in a trough of melted tallow.

The yarn then passes through another reed to a roller, which is used as a measuring roller, the colour brush for marking the yarn at the end of each piece being geared to it. Leaving the measuring roller, the yarn is again divided by a rod, and passes to a leaf of heddles, which is used for lifting the lease, and then through the crown reed, which guides it on to the weaver's beam, which is driven by friction against a drum, the speed of the yarn through the machine being thus always the same whatever the diameter of the winding on beam may be.

It must be understood that the machine is double, the same operation taking place with a like number of warper's beams at the other side, the warps meeting in the middle, and being wound upon the same loom beam.

The heat in the steam chest can be regulated to give more or less drying, and may be made double, with two fans, if required, another set of lease rods being employed. The friction or winding on drum is cone driven, so that the speed

of the machine is easily changed, and the yarn run quicker or slower through the machine. In this way heavy yarn may be thoroughly dried, while fine yarns need not be over-dried.

Various substances are used for dressing the yarn, such as flour, starch, sago, farina, and Irish moss.

Flour dressing is usually made by steeping the flour in water until it ferments (*i.e.*, till it rises up and falls again). This fermentation breaks up any lumps and also makes the dressing keep better after it is made. It is then boiled, often with the addition of tallow, and run into tubs to cool, when it should be a firm jelly, but not too thick. Before using, the dresser mixes it up with water in a bucket, until it is of the desired consistency, if it is not already of that thickness.

As dressed linen yarn becomes very brittle when the atmosphere is dry, a deliquescent or softening substance is often used along with the paste. Tallow is the usual softener and zinc chloride or chloride of magnesium the deliquescents most generally used, about 8 per cent. of tallow and from 2 to 7 per cent. of chloride being the usual proportions.

For jute yarns the usual dressing consists of 90 per cent. of farina or wheaten flour, 8 per cent. of tallow or lard oil, and 2 per cent. of zinc chloride. When farina alone is used, the mixture should not be boiled, but simply raised to boiling point.

A very good dressing for jute warps may be made as follows: Steep together for three days American sour flour and water in the proportion of 2 lb. of flour to 1 gallon of water. Add 1 lb. of alum and 2 lb. of lard oil for every 20 gallons of steep, and boil the whole together for one hour, keeping the mixture in motion while boiling.

If a softer dressing than flour paste is required for linen yarns, 75 per cent. of flour and 25 per cent. of Irish moss may be used, or the proportions may be reversed or moss alone used.

The length of warp laid must be considerably longer than

the length of the piece of cloth which it is desired to produce. For instance, to produce a 40-yard piece of 24 porter, double warp flax canvas, 24 in. wide, weighing 18 oz. per yard, with 19½ shots per inch of weft, 50 yards of warp must be laid.

When the warp has been dressed or beamed, the beam is put into a drawing frame and a set of rods put through the threads where the lease cords are. Then a set of healds are hung down from the beam and the ends drawn through the heddle eyes as required by the sort of fabric to be woven, as will be explained later on. The yarn is drawn through the splits of the reed in much the same way, by means of a reed hook, one, two or more ends passing through each dent.

CHAPTER III.

PREPARING THE WEFT.

The weft must next be prepared. It is generally purchased from the spinner or bleacher in hank form, and must be wound upon pirns or into cops for the shuttle. Fine linen yarns, however, may sometimes be had, which have been spun and dried upon perforated paper tubes in cop form, thus saving two processes, the reeling and the cop or pirn winding. Other yarns are sometimes copped by the spinner from the bobbin and sold to the weaver in the form of cops, thus avoiding the reeling process. In many cases, however, this cannot be done, as, for instance, in the case of yarn which is required in the bleached state.

There are three sorts of weft or cop winding frames. In one class of machine the spindles which carry the pirn revolve inside inverted cups or cones, which fit down upon the pirns. In others the conical cup is made a fixture and the spindle moves away from the cup as the pirn fills. In other machines the cup rests in a slide and lies upon the pirn by its own weight. As the pirn fills it raises the cup, carrying with it a small elbow lever which acts as a guide. Thus the traverse of the thread keeps invariable as regards the cup and takes up such a position upon the pirn as is required to allow for the amount of yarn upon the latter.

Figs. 6, 7, 8 and 9 show various forms of these cop and pirn winders.

Fig. 6 is an inverted spindle machine well adapted to wind cops of jute yarn from the spinning bobbin.

Fig. 7 is another form of machine for winding either coarse or fine yarn from bobbins or spools. It builds cops of any

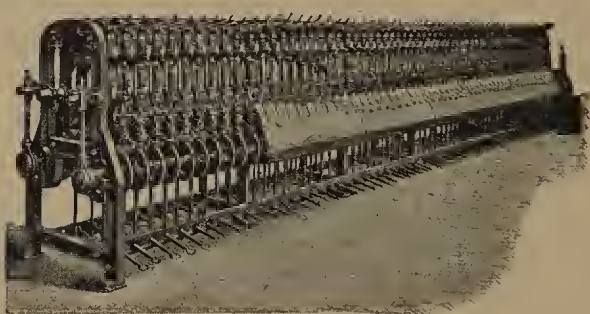
diameter up to 2 in., and any length up to 11 in. An arrangement is provided by means of which the spindles stop automatically when an end breaks or runs out.

Fig. 8 is a similar machine, arranged for winding from the reel or hank.

Fig. 9 is a pirn winding machine, adapted to the winding of both coarse and fine yarn from the hank. For winding fine and weak yarn it is supplied with extra back balance levers. The disc shafts are ring lubricated.

In Boyd's cop winder, which is well adapted to the winding

Fig. 6.



Cop Winding Machine.
Cops-Spulmaschine.
Разматывальная Машина.

of fine linen yarns, the spindles lie almost horizontally and are pressed into conical cups by means of a lever. The end of the spindle, which passes through the cup and upon which the empty tube is placed, is removable, and is driven by a clutch from the butt of the spindle which passes, on a feather, through a bevel pinion, which drives it from the spindle shaft pinion. The thread guides are fixed upon an oscillating shaft, and have a traverse about equal to the height of the cone, inside which the cop is formed. When the tube is empty it protrudes through the cup, and the yarn is lapped upon its base until it accumulates to such an extent that its diameter becomes greater than the diameter of the cone, and it is forced backwards with the spindle which drives it.

In this way, the base of the cop being formed, the sides are kept perfectly parallel, the nose of the cop being always of the same conical shape as the interior of the forming cone or cup. An ingenious stop motion is arranged in such a way that when the tube becomes full the lever which pushes the

FIG. 7.—Cop Winding Machine to wind rrom Bobbin.

spindle forward overbalances itself, and draws the cop back, when the clutch disengages itself and the motion of the spindle ceases. The firmness or hardness of the cop depends upon the tension of the yarn as it is drawn off the bobbin or hank, upon the pressure with which the nose of the cop is pressed into the cone, and upon the length of the thread

guide traverse. The cop is better bound together with a long traverse, a short traverse tending to make it easily broken.

When a thread is being wound upon a conical surface of varying diameter, it is obvious that if the spindle is kept at

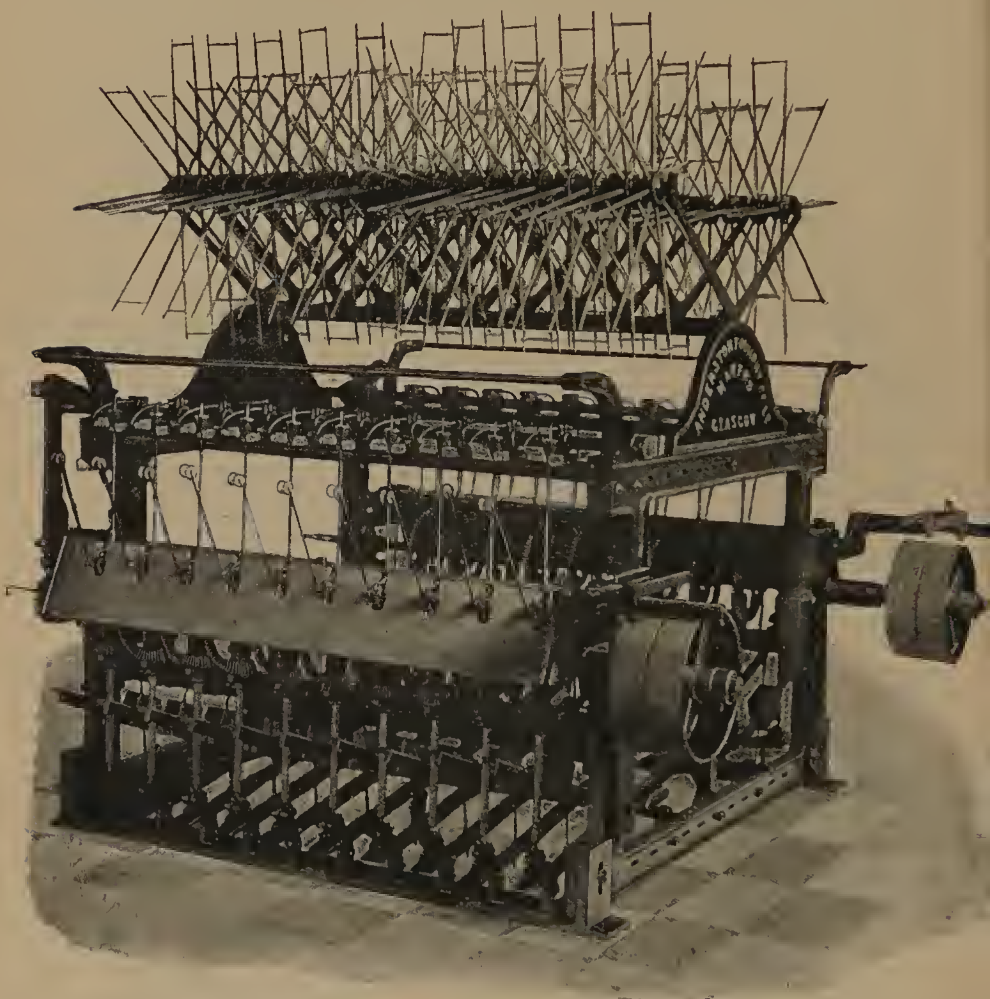


FIG. 8.—Cop Winding Machine to wind from the Hank.

a uniform speed, the velocity of winding will be greater while the thread is being guided upon the large diameter of the cone, than when winding upon its point. This irregularity is most objectionable, as it produces an unequal strain upon the yarn.

In Boyd's cop winder, the spindles are driven by gearing, as we have said, the necessary variation in the spindle speed being obtained by the use of eccentric wheels. These are arranged in such a way that one complete revolution corresponds with one complete or double traverse of the guide,

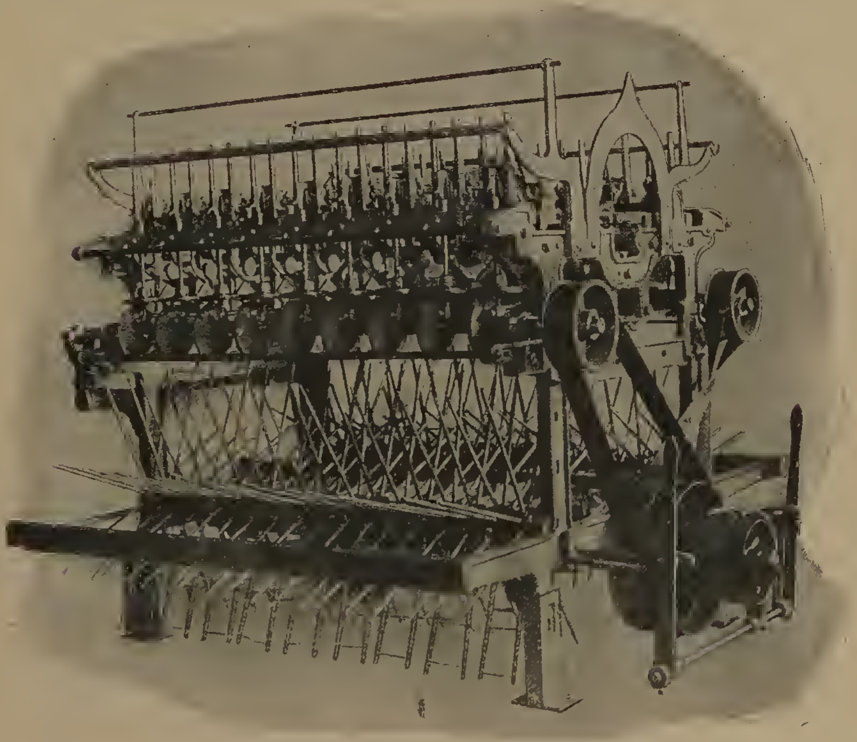


FIG. 9.—Pirn Winding Machine.

the eccentricity of the wheels being such as to exactly allow for the different diameters of the cone.

In a certain Dundee machine, the copping spindles are driven by the friction of narrow-edged pulleys upon the flat surfaces of leather-covered discs. At the moment when the yarn is being guided upon the larger diameter of the cop, the edge of the pulley is driving upon the outer diameter of the disc, and as the traverse approaches the smaller diameter of

the cone, the pulley approaches nearer the centre of the disc, and, of course, drives it faster. These discs are mounted upon the spindles face downwards, near their lower end, and the pulleys are fitted upon a shaft running along the machine below the discs, and provided with an end traverse. This shaft being rotated, conveys its motion to the spindles, and the traverse is so calculated as exactly to compensate for the different diameters of the cone.

With hard and slippery material, such as flax, hemp and jute yarn, which has no clinging properties, a good firm cop cannot be built without considerable tension or pressure.

When wound upon the bare spindle, the thread may be drawn from the inside of the cop and the shuttle peg dispensed with, the shuttle forming a kind of box in which the cop is enclosed. When wound upon a wooden pirn or paper tube the end is drawn from the nose of the cop, which is held in the shuttle upon a tongue or peg. There is an ever-increasing tendency in the trade towards the universal use of cops, owing to the greater length of yarn which they contain and the less frequent stoppages of the loom for shuttle changes which their use entails.

Cops produce better selvedges than pirns, because when pirns get nearly empty, there is considerable friction of the thread upon the barrel of the pirn and consequent tension, which causes uneven selvedges on the web, and has a tendency to break the selvedge threads.

The dimensions of the pirns or cops which are used has a very material effect upon the weaving. Large pirns or cops mean fewer stoppages of the loom to change the shuttle when the weft runs out. Cops of large diameter require big shuttles, a large shed, and put a greater strain upon the warp threads. As the shuttle can be changed several times over during the time required to mend one broken warp thread, a happy medium must be chosen as regards the diameter of the cop or pirn. As regards their length, they should be

as long as practicable, a long shuttle and consequently long shuttle boxes being the necessary accompaniment of a good working pick.

The shuttle is an indispensable organ of the loom, and it is of the utmost importance that it should be suitable for the class of goods to be woven. Shuttles are made of various sorts of wood, and at various prices. Cheap shuttles are often dear at any price. Many weavers prefer boxwood shuttles, but cornel wood is also much used in their construction, and it is not so heavy. When shuttles arrive at the mill they should be steeped in oil for a few weeks, and then thoroughly dried. Before being put into the loom the shuttle should be thoroughly examined, to make sure that it is of exactly the same length, breadth, height, and weight as the other shuttles with which it is to run, this being a most important point if the loom is to run properly.

The shuttle is an almost rectangular piece of hard, polished wood, tapered at the ends and tipped with iron. The shuttle itself should be smooth, and the edges slightly rounded, especially the near top edge, which comes most in contact with the top yarn. An average jute shuttle is about 20 in. long and 2 in. square, and weighs about 2 lb. For fine linen fabrics the shuttle may not weigh more than 12 oz., while for heavy canvases it may be up to 3 lb. in weight. Generally shuttles are put into the loom with the eye end nearest to the weft fork when in that box, although there are mills in which the opposite plan is the rule. They are also sometimes made right- or left-handed, *i.e.*, with the eye at the right or left hand end of the shuttle.

CHAPTER IV.

THE LOOM.

Figs. 10 and 11 show two types of jute and linen looms. Fig. 10 is the front view of a hessian loom, showing the sley and reed, the breast and cloth beams, while fig. 11 is a front view of an underpick linen loom, the other loom shown being of the overpick type.

Picking is the driving of the shuttle carrying the weft from side to side of the loom, through the "shed" formed by the warp threads, as some of them are held up and some down by the heddles.

There are, as we have hinted, two types of picking mechanism used in jute and linen looms—the overpick, which is almost universal in the jute trade, and the underpick or lever-pick, which is very much used in the linen trade, being cleaner, and giving a sharper pick, which is an advantage in slow-running looms.

In the overpick loom the picking arms proper are wholly above the shuttle boxes, as seen in fig. 10, while in the underpick loom the picking stick or sword moves about a fulcrum at its base and near the floor, its upper extremity passing through a slot in the bottom of the shuttle box. The picking mechanism of the overpick loom consists of a picking wyper, or tappet, keyed to the bottom or wyper shaft; also of a stud which carries a conical anti-friction roller, and which is bolted in a tapered hole in a vertical shaft, to the top end of which

the wooden picking arm is clamped. The top of the vertical shaft is made in two parts, an upper and a lower, the faces of which come together, and are saw-toothed to ensure a rigid grip while permitting any necessary adjustment in the position of the arm. As the bottom shaft revolves, the wyper drives the cone stud through a certain angle, causing the vertical shaft to make a partial revolution and the picking arm to do likewise. A leather strap or picking band, not shown in the illustration, is connected to the extremity of the picking arm

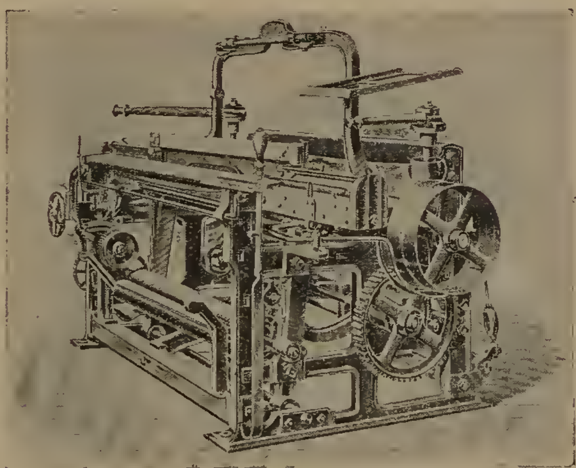


FIG. 10.—Hessian Loom.

and to the buffalo-hide picker on the picking spindle, and thus gives motion to the shuttle.

In the underpick loom the picking stick or sword, which may be seen to the right in fig. 11, is given a quick throw by means of a picking bowl carried on a wyper, keyed upon the wyper shaft. This picking bowl acts upon a plate bolted to a horizontal picking lever, fulcrumed at one end in the framework of the loom, the free end bearing over the short arm of a bracket, which carries the picking stick, and surrounds the stud which forms the fulcrum upon which the picking stick oscillates. When the bowl depresses the lever, the short

arm of the picking stick lever is likewise forced downwards, and at the same time the upper end of the sword is compelled to travel rapidly inwards, and thus propel the shuttle. The stick is returned to its position by means of a spring and a strap attached to the bracket, the spring also serving as a buffer.

The shuttle often moves with a velocity of 40 ft. per second. It is brought to a stop at the end of its journey by the "swells" of the shuttle boxes into which it runs at

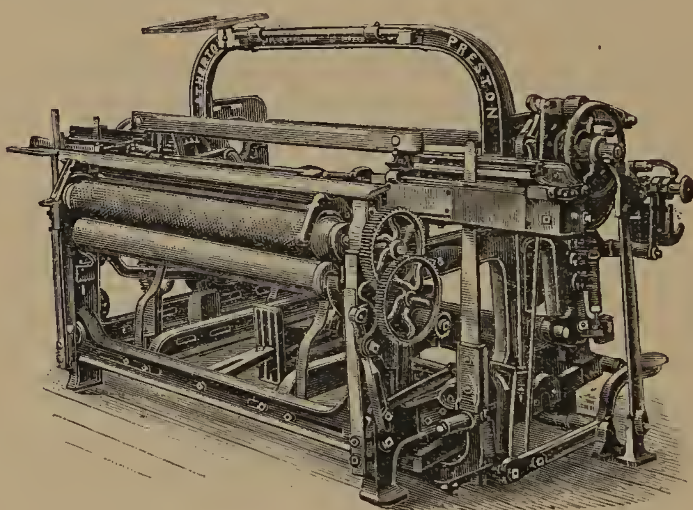


FIG. 11.—Underpick Linen Loom.

either side. The pressing out of the swell raises the tongue of the warp protector clear of the "knee," or buffer, and thus permits the motion of the loom to continue, or another pick to be made. Were the shuttle to remain in the shed, the swell would not be pressed out, nor the tongue of the warp protector raised, and the loom would be brought to a stand-still before the warp threads were broken by the presence of the shuttle in the shed and between the reed and the lay of the cloth.

The loom picker, through which the throw of the picking

stick or sword is imparted to the shuttle, should be of well seasoned and compressed leather. Quite a different pattern of picker is required for overpick and underpick looms. That required for the former loom is usually made of buffalo hide, while underpick or brown pickers are of cow hide.

Various shuttle guards are applied to the loom to prevent the shuttles flying out. They never try to do so without cause, however. The causes of shuttles flying out are numerous. Anything which has a tendency to throw the shuttle out of a straight line, while it is moving from box to box, will cause it to fly out. The reed forms the back guide and the race board the bottom guide for the shuttle in its passage across the warp, leaving the top, front, and both ends open for the shuttle to leave the loom if its course is diverted by a broken thread or knot in the shed, or by an uneven blow of the picker. Sometimes the picker spindle is not exactly parallel, so that the picker does not give the shuttle a straight blow, but one that deflects the shuttle, causing it either to fly out, or the loom to bang off. Sometimes the hole into which the taper end of the spindle fits is a little large, and as the picker moves backwards and forwards on the spindle, the latter moves also, giving the shuttle an uneven blow which will cause it to fly out. If the spindle hole of the picker is not reamed out true, the shuttle may be thrown out. The sweep of the strap also has an influence on the movement of the shuttle. If the strap is made so short that the blow of the picker ball is immediately communicated to the picker stick, the movement of the shuttle will be jerky, and the probabilities are that it will be occasionally thrown out. The sweep of the strap should be sufficient to impart the blow of the picking ball gradually to the picker stick. The slack of the strap is first taken up for the blow, and then the force is imparted to the picker stick, with the result that the blow of the stick on the picker and shuttle is free from jerkiness. If the picker stick is not true and square

where it fits into the picker, it may impart an uneven blow or movement to the picker, thereby causing the shuttle to move out of a straight line. If the hole in the picker head is uneven, it will cause the shuttle to fly out by imparting a crooked motion, but it may not do so every time, as the deflecting motion may be imparted only at intervals, or instead of throwing the shuttle out of its shed, the tip may be raised so that it will break the warp threads. With the picking motion, which includes picker, strap, spindle, and picker stick properly working, there is not much liability of the shuttle being thrown out unless there is a defect in the raceboard or reed. If the reed does not form a perfectly straight line with the back of the boxes, the shuttle will be deflected from a straight line and thrown out of the shed. A straight edge laid from box to box will always tell whether the reed is out of truth or not. A bent dent in the reed will deflect the shuttle from a straight course, and cause it to leave the shed. A worn raceway will also cause trouble by occasionally throwing out the shuttle; it should then be taken out of the loom and planed down true.

To adjust the picker stroke, both cranks on the crank shaft are moved till they point vertically downwards. This opens the shed more than half-way, the lathe being moved half-way towards the rear, and since a short time will elapse before the picker strap becomes tightened and the shuttle arrives at the shed, the nose of the tappet may now begin to engage with the striking roller, in fact, the latter should rest exactly in the hollow of the tappet. Slots are provided in the tappet to enable its nose to be adjusted and fixed by the aid of a couple of screws. To quicken the stroke, the screws are loosened and the nose drawn forward, whilst for retarding the stroke the nose is pushed further back and then refastened by tightening the screws up again. To fix the strikers, the loom is moved round until the point of the tappet nose points exactly to the centre of the roller. The

roller must not project above the nose. It is best to key the tappet in such a way that the extreme point of the nose coincides with the edge of the roller. Should the stroke be not sufficiently powerful, a remedy is afforded by fixing the roller in a lower position in the slot in which it is mounted. The attachment of the picking strap to the striker is effected by inserting the strap into the slot from the outside and by winding it round the striker so that it is stretched almost taut between the striker and picker which must then be in position for action.

The shuttle should not enter the shed until the latter is sufficiently open and the lathe drawn far enough back. The speed of the shuttle must be sufficient to cause it to leave the shed before the latter begins to close. Should it enter too soon or leave too late, the result will be the breakage of the threads at the edges of the warps or faults will be produced by the shuttle missing some of the threads.

Linen and jute looms cannot be driven very quickly, as the warp yarn is brittle, especially when dressed, if the air is not moist enough. One hundred and sixty-five picks per minute is a good average speed for 4/4 linen looms although they are sometimes run up to 240. For hessians, 125 picks per minute is the usual speed.

For light linens, a good calico loom weighing about 16 cwt. for a 4/4 loom will do, but for heavy work, stronger, heavier and more rigid looms are required.

Jute looms must be very strongly constructed so that they may withstand the strain of weaving heavy goods. A wide and firm shed is required owing to the strong and unelastic nature of the warp and the liability of the shed to be choked through the friction of weaving causing an accumulation of loose fibres among the warp threads. The shuttles are of large size on account of the thick weft, and require a powerful stroke from the picker to drive them through the shed, while considerable force and strength is required to beat up the

weft so as to obtain the number of picks per inch required for some heavy cloths.

The lay or sley upon which the shuttle runs through the shed and which carries the reed which beats up the shots is supported at either end by two vertical pieces called the swords, which are fulcrumed at their extremities in the framing. The swords are connected by means of rods with cranks upon the crank shaft which is placed in a lower plane than the pins by which it is connected to the swords. The result is that the slay is given an oscillating movement backward and forward, the backward motion slow, in order to allow the shuttle time to get across, and the forward motion quick to save time and to beat up the weft smartly. The distance which the crank shaft should be below its point of connection with the sword is equal to half the diameter of the circle the crank describes.

The throw of the crank must be increased in proportion to the width of the loom so that the shuttle may have time to get across.

Any one at all conversant with the manufacture of cloth knows what an important part the reed and sley play in the production of a perfect fabric. As previously explained one of the chief purposes of the reed is to act as a gauge by which the fineness of the cloth may be indicated. In addition the reed is used in weaving (1) to separate the ends of warp and to arrange them in their required places in the cloth; (2) to serve as a guide for the shuttle in its passage across the loom; and (3) to beat up the weft to the preceding picks.

In ancient times, reeds were made of reeds, rushes or strips of cane or wood, but now steel or a good quality of iron wire is used. Reeds should always be sufficiently deep to allow of a shed of suitable size for the shuttle being formed without the upper threads touching the top of the reed. In many cases the attachment of shuttle guards makes the substitution of deep reeds or narrow ones advis-

able, as some forms of shuttle guards are apt to come into contact with the temples. The reed being used as a guide for the shuttle necessitates that some attention be paid to the position and method of affixing the reed in the lay and lay cap. The centre of the reed should be a little further back than the sides as this enables the shuttle to be kept against the reed on its passage across the loom. The broader the loom, the greater the bend of the reed. Care, however, must be taken that the ends of the reed do not project in front of the box backs, otherwise the shuttle will not run straight and may be thrown out. When beating up, the reed should be vertical or upright when at the fell of the cloth, as sometimes the weft is slightly cut or frayed, when the reed beats up, if it is inclined at an angle.

In the loom, 2 ft. is a convenient height for the back beam and the top of the breast beam. The "stretch" or distance over back and breast beams may be 3 ft. 6 in.

The crank shaft makes two revolutions for one of the wiper shaft, for the former makes a complete revolution for each pick, while one revolution of the latter produces two picks, the shuttle being thrown from both sides.

Another important organ of the loom is the heddle or shed forming motion. The headle or healds consist of twine looped in the middle, through which loops or eyes the warp threads are drawn. The heddles are fastened top and bottom to shafts or laths, each set being called a leaf. At least two leaves of heddles are required for plain cloth, one half or every alternate thread passing through the front leaf, and the remainder through the back leaf. The number of eyes used in each leaf corresponds in this case with the number of splits used in the reed, if there be two ends per split as there usually are. If the reed is so fine that the heddles cannot be placed close enough together, two leaves may be bound together and used as one. If the sum of the eyes corresponds with the splits in the reed on a

given width, all the eyes are utilised. If there are too many eyes, some may be left empty singly at regular intervals.

Twills are produced by the use of 3, 4 or 5 leaves of heddles, huckaback with 4 leaves, and dimities with 3 and 4 leaves.

The shed is formed by the up and down motion of the heddles, some of which are raised, and the remainder lowered for each revolution of the crank shaft. The raising of the shafts or the formation of the shed is effected by means of tappets and treadles when the number of leaves of heddles is not too great. Tappet looms may be divided into two classes, inside or central, and outside treadle looms. In the inside treadle loom the tappet for plain weaving is generally mounted on the picking tappet shaft. In the outside treadle loom, which is usually constructed for as many as 6 shafts of heddles, motion is imparted from the main shaft through wheels on the picker shaft, on which—outside the framing—a cannon wheel, made in one piece with the cog wheel, is pushed on to the tappet and fixed thereon by clamping screws. For plain cloth, the leaves of heddles, which move up and down alternately, may be joined together by straps passing over jacks or pulleys, so that the depression of one leaf or leaves by the tappet and treadle raises the other or others, or the leaves may be united by straps to bowls upon a jack shaft above them, which straps are wrapped upon the bowls or bosses in different directions, so that the shaft is caused to oscillate by the up and down motion produced by the treadles. In the outside treadle loom, the reversing or under motion is effected by springs attached to the floor. The ordinary wyper tappet is generally used for plain work, and the Woodcroft or built up outside tappet for twills, but the plates of the latter tappet are better cast solid than built in sections. If the work is heavy, under tappets with stocks and bowls above are much firmer.

The following important details connected with the shedding

motion should not be forgotten. The movement of the heddle leaves should be eccentric, so as to minimise the strain and consequent breakages of the warp threads. The treadles must be in continuous contact with the wypers throughout the whole revolution. The shed must be full open when the shot is being beaten up. The length of stroke given to the wypers or tappets is to the distance from the point on which the treadles move to their point of contact with the wypers, as the distance the heddle leaves will move is to the whole length of the treadles.

CHAPTER V.

FIGURE WEAVING.

A PATTERN or figures are produced in weaving by bringing the warp and weft to the surface as desired. When to form the design a large number of picks are required before the pattern repeats itself, a dobby or a Jacquard machine must be used. Fig. 12 shows a combined damask or jacquard and dobby machine. It has 102 damask hooks, and eight hooks for working shafts of heddles. This machine is largely used

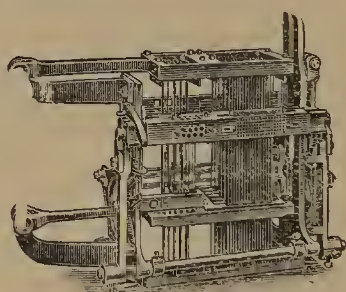


FIG. 12.—Combined Damask and Dobby Machine.

in the manufacture of glass cloths, railway, hotel, and steamboat napkins, &c., &c. It is fixed upon the upper part of the framing of the loom which is made high to carry it.

The machine fig. 13 is mounted in a similar manner. It is a 400s two-cylinder compound Jacquard machine, with cylinder motion for cross border weaving. This machine, which is designed for cross border weaving, can be used for other work as well. It can be worked on three different principles, viz.: as a double lift double cylinder machine, or as a single lift machine for cross border work, one cylinder

working the border and the other working the middle of the cloth. The machine contains 800 hooks and 800 needles, and by bolting the two griffes together it can be worked as an 800 single lift machine. When the machine is used for cross border work, there are two connecting rods from the machine to the loom, one for working the ground and the other the border as required. This machine is made in different sizes from 100^s to 1,320^s needles.

The Jacquard machine was invented in 1805 by Charles Jacquard, of Lyons. It provides a means by which every

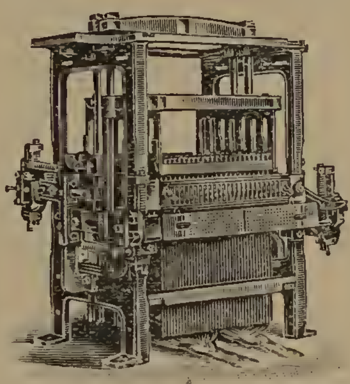


FIG. 13.—400^s Two-Cylinder Compound Machine.

individual thread of warp may be placed either above or below the weft at every shot. Before the invention of the Jacquard loom, when it was desired to produce figured goods, it was necessary that all the warp threads which should rise simultaneously to produce the figure, should have their appropriate healds which were grouped together into systems, which a child or draw boy raised by means of cords, in the order and at the time desired by the weaver. This plan evidently occasioned no little complication in the mechanism when the design was richly figured, so that the Jacquard apparatus has been generally adopted.

The Jacquard machine consists essentially of a number of upright wires held in a frame at equal distances. Each

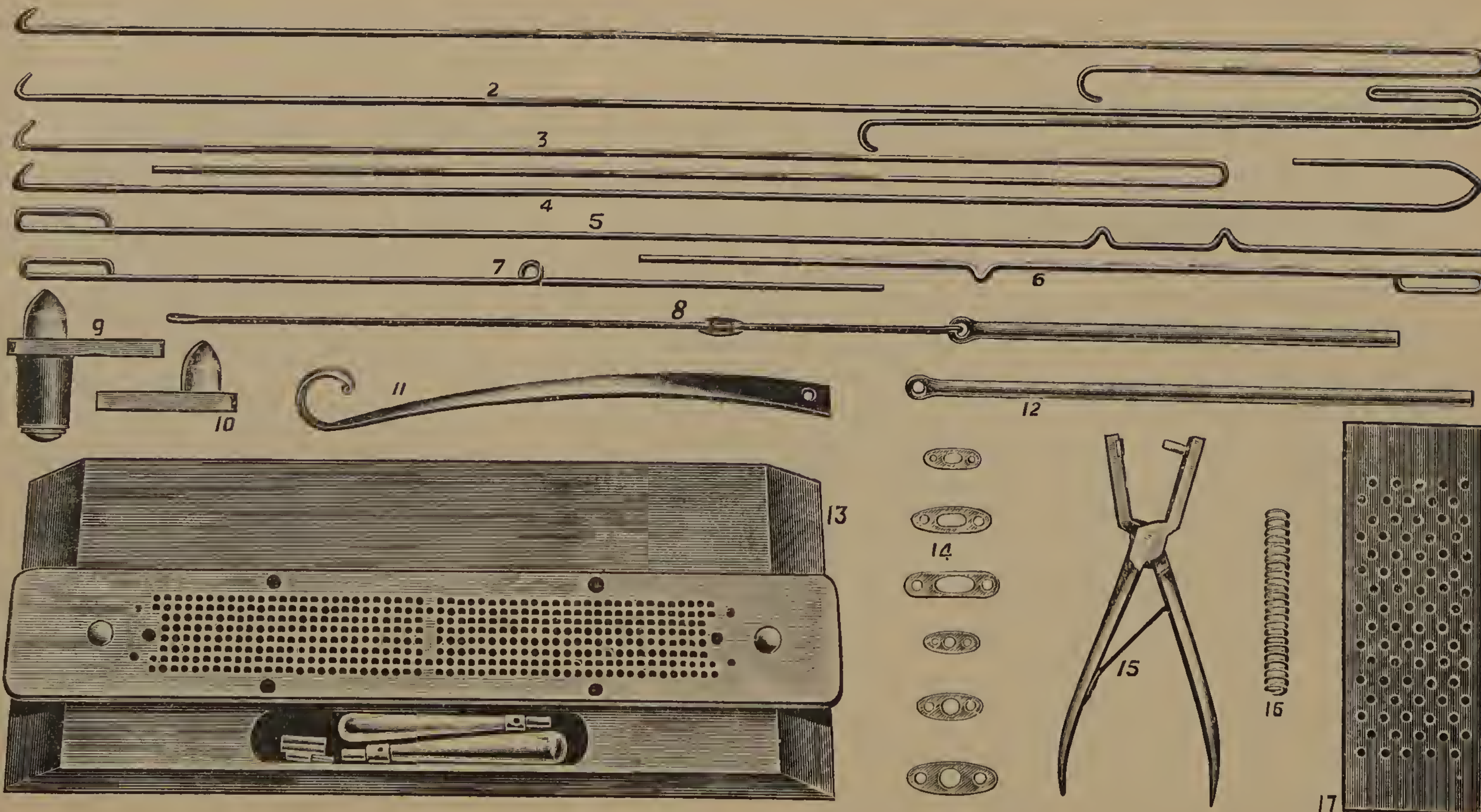


FIG. 14.—Sundries.

wire corresponds to an eye of the heald, and the object of the mechanism is to ensure the independent raising of any of these wires as they may be required to form the pattern. The wires are usually made as seen in fig. 14, with a hook at the top and a long flat loop at the bottom. They are arranged in rows, and through the bottom loop of each row a rod is passed so as to keep the open side of the hook turned in the same direction. To the bottom loops cords are attached, leading down to corresponding threads in the warp, and the top hooks are so placed as to be acted upon by a frame containing a series of bars or knife blades, one blade to each row of wires, and they may thus be raised at any time by raising this grid frame. By the use of cards and selecting needles, any desired wires are removed from proximity to the raising blades, so that they are not lifted as the grid frame rises.

The needles are employed to select the wires necessary to be raised in the formation of a shed. They are arranged horizontally in rows at right angles to the wires, passing at the back of the machine into a spring box, and at the front projecting a short distance through a needle plate. It is here that the cards are presented; the holes in the needle plate are an exact repetition of those in the card cylinder so that when the latter is brought into place the two sets of holes coincide. The spring box is a duplicate of the needle plate as far as the number and position of the holes is concerned, but carries a small spiral spring for each needle. These springs keep the needles always projecting to an equal distance through the plate except when the card cylinder is brought into place, when any needle not having a corresponding hole cut in the card is pressed back against the force of its spring.

Each upright wire passes through an eye in the needle, so that when any needle is pressed back by a card, it carries with it a corresponding wire without interfering with the free vertical movement of the latter.

The card cylinder is a square prism. Each face has in it a series of holes corresponding in number and position with the needles of the machine. The card cylinder is given a reciprocating motion corresponding with each revolution of the crank shaft and with the formation of each shed. It is also pulled round through an angle of 90° prior to the formation of each shed. A chain of perforated paper cards is passed round the cylinder and is held in position by two conical pegs in each face, the pegs passing through

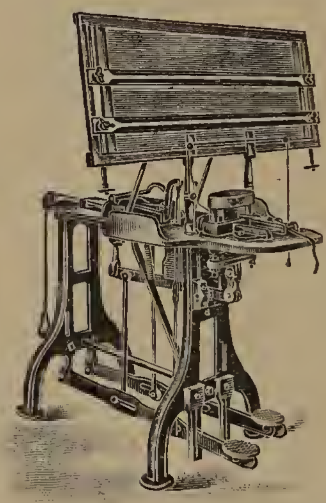


FIG. 15.—Piano Card Cutting Machine.

holes in the cards. The cards are punched to correspond with the pattern to be woven, each hole equalling a rising thread and each blank a sinking thread. The rotary motion of the cylinder brings the cards forward successively, and the horizontal motion allows the cylinder to turn, and also moves it into contact with the projecting points of the needles. The cylinder moves out when the grid frame is above the level of the hooks which have been left down, far enough for the catch to turn it without bending the needles; a fresh card is presented and the process repeated. The different makes of Jacquard's may be classed as single

acting, centre shed, double acting single cylinder, double acting double cylinder, open shed, twilling, &c. In describing a machine, it is usual to mention the number of needles it contains, omitting those intended for selvedges.

The Dobby machine is often called a little Jacquard. It is of the nature of the tappet motion, inasmuch as it lifts the yarn in healds and not by single ends as the Jacquard, and shares with the latter the arrangement of forming the pattern by a series of cards. The dobby is made to work

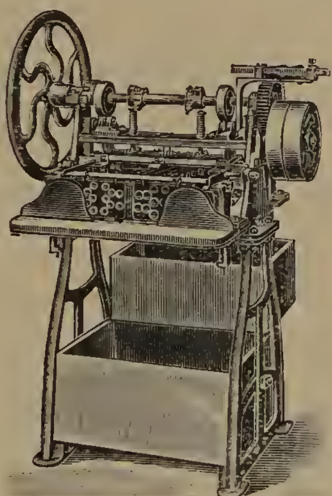


FIG. 16.—Peg and Lace-hole Cutting Machine.

up to eighteen and twenty shafts, with an almost unlimited length of pattern. The heddles are raised by levers or jacks, which latter are lifted at one end by the hooks of the dobby, These hooks work in a similar way to those in a Jacquard, and are acted upon by griffes. Like the Jacquard, these dobbies are now mostly made double lift to increase their speed, *i.e.*, one griffe goes up while the other goes down, thus necessitating a double number of hooks. A good dobby, if strong, and of positive tread, does very well for light and medium work, but it is not rigid enough for heavy work. A right hand dobby is one in which the driving rod or rods

pass down at the left hand end of the loom, as seen from the weaver's stand.

Cards containing two or three rows of holes are often met with on dobbies having only one row of needles. A manufacturer is thus able to produce long striped or bordered fabrics from a few cards, each row being cut to weave a different pattern. The card cylinder is, of course, drilled to correspond with the number of rows in the card, and the dobby is said to be double-decked for two and three-decked for three rows.

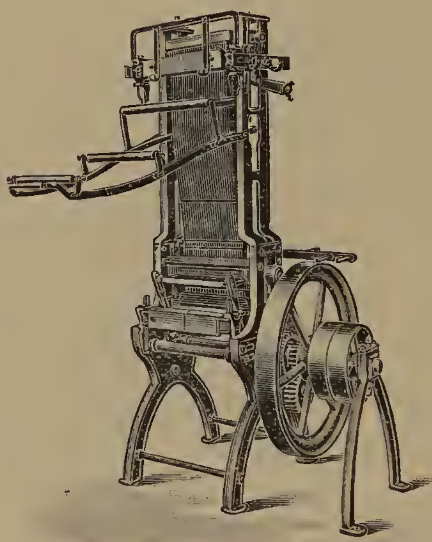


FIG. 17.—Jacquard Card Repeating Machine.

For the fancy classes of linen the Jacquard is chiefly employed. Linen damasks, tablecloths, napkins, doilies, teacloths, &c., are made with it. There are two styles of damask weaving—full harness and common or pressure harness. The first is woven with the Jacquard only, and one thread through each mail. The second is woven with the Jacquard and leaves combined. It may have two, three, or four threads in the mail, but in drawing it through the leaves of heddles, it has a thread for each heddle. If it has five leaves, it is termed single damask; if eight, double damask.

Shedding motions are of two kinds, the open and the closed shed systems. In the open shed system, the shafts which are once raised are kept in that position until the pattern requires them to be depressed. In the closed shed system, on the other hand, every shaft is brought down to a level after each pick, even if it is required to rise again for the next. The former is to be preferred, as the yarn is not so much slaved in forming the shed.

Cards are pieces of pasteboard cut into such lengths and widths as are capable of covering the needle space of any

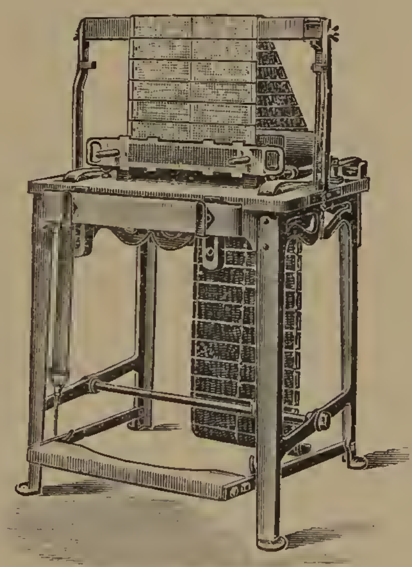


FIG. 18.—Repeating Machine Table.

machine with which they are intended to be used, and also of leaving room for lacing and holding them upon the faces of the card cylinder.

Fig. 15 is a piano card-cutting machine, made to cut cards from the design, and will cut up to 600's cards, or can be made to cut any other length of cards, and to any pitch.

Fig. 16 is a peg and lace-hole cutting machine, made so that holes in blank cards can be cut correctly, and to correspond with the punches in the self-acting repeating machine, fig. 17.

With the aid of the peg and lace hole cutting machine a boy or girl can cut cards as quickly as they can feed it. The Jacquard card repeating machine is an adaptation of the Jacquard principle to card punching. It easily cuts forty cards per minute.

In the piano cutting machine, fig. 15, the design is carried upon the board as shown. There is a straight-edge provided to assist the cutter in reading. The punch block is connected to a treadle, and the punches are inserted in such a way as to yield freely when touching the card unless the keys belonging to the punches are pressed by the fingers into

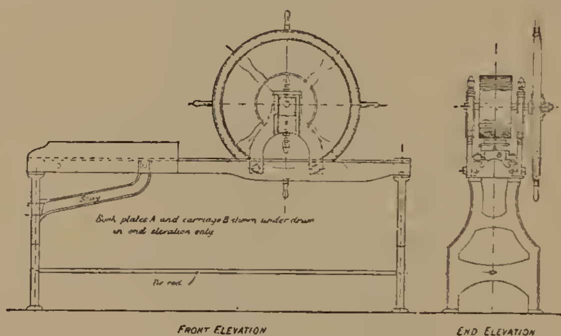


FIG. 19.—Railway Press.

gear with the punches. The first holes punched are the lace holes, then the peg holes, then the pattern is cut according to design, then the second peg holes, and another pair of lace holes.

Fig. 18 represents a 400^s repeating table, and is used for repeating cards from the original set, which is placed over the cylinder at the top of the machine, and by pressing the treadle the punches are placed in the top plate from the punch box, according to the holes in the card requiring to be copied. The plate is then placed on the carriage of the press on the top of the plates containing the blank card, and is then slid to the drum of the railway press, fig. 19, which, being turned, pierces the required holes.

Two cords are used for lacing the cards, and are crossed through the lacing holes, and also between the cards.

CHAPTER VI.

MOTIONS OF THE LOOM.

The distance from the back beam of the loom to the fell of the cloth or to the point to which the weft is driven by the reed, must be pretty large as compared to the size of the shed formed, for it is plain that the strain upon the yarn in forming a shed is roughly proportional to the angle between the upper and lower halves of the shed, and this is largely governed by the distance between the back beam and the cloth. If there is any elasticity in the yarn, a comparatively long thread will give more stretch in order to meet the strain of shedding than will a short one. For this reason the loom beam is placed as low as possible so as to provide between the yarn beam and the back rail as great a length of thread as practicable. In no class of weaving are these considerations of more weight than in weaving such inelastic yarns as those of flax, hemp, and jute.

Another important movement of the loom is that required to beat up the weft. Subsidiary to this is the take-up and let-off motions, or those mechanisms which wind up the woven cloth as made and let off the proper quantity of warp from the yarn beam. The main driving shaft which extends across the loom and is carried in bearings upon both frames, provides the means of reciprocating the batten, ley or sley, by means of cranks formed upon it.

The oscillation of the batten should not be uniform. It should have a quick advance to give the blow which drives up the weft, a quick return motion and a point of dwell, or rather a much slower motion at the back to admit of the

passage of the shuttle in the widest open part of the shed. This eccentricity in the movement of the lay depends upon two factors, which we give in order of their effective value.

Firstly, the length of the connecting rod in proportion to the throw of the crank, and the position of the crank centre with regard to the point of attachment of the connecting rod to the lay.

The motion of the batten must be more eccentric for wide looms than for narrow ones, for the wider the loom the longer the time the shuttle will occupy in travelling from box to box.

The movement of the swords which carry this batten is generally to and from a vertical line, being vertical to the line of the warp at the moment the reed strikes the cloth.

To produce well-covered cloth the line of the warp requires to be depressed from the horizontal when the shed is closed. Otherwise expressed, the warp should at that moment slope downwards from the breast beam to the healds and thence upwards to the back rail. On this account, the upper half of the shed will always be slacker than the bottom part, and hence the upper warp threads tend to spread themselves between the threads of the tighter shed. On the other hand, when the cloth is to be open like some sorts of canvas, the line of the warp must be quite horizontal or in a straight line from breast to back rail at the moment when the shed is closed. The two halves of the shed are thus alike in tension and there is not the same tendency of the yarn to spread.

Covering the cloth in the fashion mentioned puts an increased strain upon the yarn, so that the principle must not be pushed to extremes. The tension caused by shedding is sometimes reduced by the use of a vibrating or oscillating shell used instead of a back rail. Sometimes the vibration of the shell is produced by a properly-shaped cam and sometimes by the mere strain of the warp.

The lease rods are an important adjunct of the loom. They consist of two rods inserted in the warp at the back of the healds at such a distance that the healds are about half way between the rods and the cloth. They form a lease or are so placed that they keep separate every alternate thread above and below the rods. These rods are usually made of pine and are oval in section. The section of the front rod should be as small as possible, for if the two sheds formed are exactly equal in size, the tension of the warp will differ considerably from one to the other.

The let-off motion of the loom determines the rate at which the yarn is drawn from or given off by the yarn beam. It works in conjunction with the up-take motion to regulate the travel or "pace" of the yarn. Hence both are sometimes called pacing motions. Let-off motions may be divided into two classes, *i.e.*, negative and positive. The former simply puts a break on the yarn beam, which is pulled round by the up-take and shedding motions. Most jute and linen looms have negative let-off motion.

A common arrangement for light cloth consists of a chain or rope which is passed round the beam head, attached by one end to a fixed hook and at the other to a lever fulcrumed on a stud and held down by a weight. As the yarn beam empties the weights require to be moved nearer to the fulcrum of the levers, since the pull of the yarn is on a shorter radius. For jute fabrics and for heavy linens a more powerful arrangement should be adopted.

A very good arrangement consists of wrought iron bands, lined with leather, which are attached at one end to fixed hooks, and at the other by a chain and an adjustable screw to the short arm of a lever, the long arm of which may be depressed by the weaver when she desires to slacken the friction in order to turn the beam back or forward by means of a hand wheel, side shaft, bevel pinion and wheel.

When a positive let-off motion is applied, the yarn is usually

drawn from the beam by a pair of rollers, the surface speed of which must be slightly greater than that of the sand beam or feed roller which draws the cloth forward at a speed corresponding with the number of shots of weft required per inch. This difference in the surface speed of back and front rollers is necessary on account of the contraction of the warp threads due to the insertion of the weft in each shed.

The motion of the feed roller or sand beam is a positive one produced by gearing. The rule to find the number of teeth required in the change pinion to produce a given number of shots per inch of cloth is as follows: Multiply the number of shots on one inch by the circumference of the feed roller in inches. Divide the product thus obtained by the number of teeth in the ratchet wheel, and use the quotient as a divisor in dividing the number of teeth in the feed roller wheel.

The power loom is sometimes provided with "temples" to distend the cloth during weaving. In weaving jute and coarse linen fabrics, such as canvas, sheetings and plain cloths generally, temples are unnecessary, and their use is far from general. The object of stretching the cloth from selvedge to selvedge is to minimise as much as possible the lateral strain of the warp upon the dents of the reed at and near the selvedge, and to reduce the tendency of the reed to saw and chafe the warp at these points. For wide cloth where production is comparatively slow, the hand temple, consisting of two wooden arms fitted with a series of sharp spikes at their outer and broader ends, is still used to a considerable extent. The spikes are inserted into the cloth about $\frac{1}{4}$ inch from the edge of the selvedge, and the cloth is protected from the wood by a piece of leather pressed to the root of the spikes.

Self-acting temples, such as the segmental ring temple, are, however, in far more general use. This sort of temple consists of a spindle on which a series of inclined brass rings are fitted.

These rings are about $\frac{7}{8}$ in. in diameter, and $\frac{3}{16}$ in. thick, and have one or two rows of short, sharp spikes projecting from their periphery. The spindle is bolted to the temple holder which is then passed through a bracket, which is in turn bolted, near the selvedge of the cloth, on a round or square rod, attached to the front of the breast beam. A brass cover is attached to the holder, and serves to protect the weaver and to deflect the cloth sufficiently to grip the rings. As these rings rotate with the movement of the cloth, their inclination is such that the first point of contact of the cloth with the rings compels the former to move outwards. The number of rings on a spindle is usually ten or twelve.

The weft-fork automatic stop arrangement is an important organ of the loom, for it often happens that the weaver omits to stop the loom directly the shuttle is empty, either through carelessness or through the fact that he or she is minding a pair of looms. It may also happen that the weft breaks. In any case, if no automatic stop-gear were provided, faults, consisting of thin places or a total absence of weft threads, would result. To prevent this a weft fork is affixed on the driving side, which fork, on the advance of the lathe, fits into a grid constructed in the latter. This fork is also put in connection with the starting lever, and while the loom is in gear is forced by the action of this lever in the direction of the lathe, so that when the crank reaches its front dead point the fork projects a short distance through the grid when no weft thread is across it. At the end of the fork opposite to the prongs is a small hook, which, at the instant under consideration, descends. On the other hand, if a weft thread prevents the prongs of the fork from passing through the grid, the hooked end is raised.

A movable lever is mounted on the frame, just below the breast beam, and is provided at one end—where it has a vertical movement between the beam and the lathe—with a catch to engage with the before-mentioned hook. The other end of this lever rests on a tappet, or on a bowl attached to a lever

mounted on the tappet shaft, the said tappet being adjusted in such a way that when the crank is in its foremost dead point (*i.e.*, the one next the cloth), the slightest forward movement of the loom causes the tappet to lift the lever arm. As the tappet roller makes only one revolution for every two picks, it results that the movement of the lever arm follows every second pick. Consequently, in the above-named position of the crank shaft, the shuttle must be in the box on the driving side: *i.e.*, the last pick must have been from the opposite side of the loom to the driving side. If now, as already contemplated, a weft thread lies between the prongs of the fork and the grid, the hook is lifted and the catch on the bent lever moves away underneath. If, however, the weft thread is absent, then the prongs project through the grid, the hook descends and, being engaged by the bent lever, is drawn forward, the lever connecting the fork with the starting lever comes into play and pushes the latter out of its notch, thus throwing the belt on to the loose pulley.

To prevent the ratchet wheel of a positive take-up motion from pulling the cloth one notch forward after the empty pick and leaving a faulty place in the cloth, a projecting tongue, connected with the pawl by a bar underneath the breast beam, is provided in the starting-gear plate and is drawn forward when the fork lever is depressed, thus disconnecting the pawl from the ratchet wheel.

The stop-rod or shuttle-protector is another organ of great importance in power looms, its object being to protect the warp from injury in the event of the shuttle, from any cause, failing to reach the shuttle-box and leave the shed before the reed beats up to the cloth. There is a "frog" or stop attached to the front of the framing of the loom. A lever comes in contact with this stop if the shuttle is not in the box at the proper time, but if the shuttle reaches the box in time it presses back a spring or lever, which acts upon the first-mentioned lever and raises its point, so that it clears the top of the "frog" as

the lay makes its forward stroke; but if, as we have said, the shuttle does not enter the box, the point of the lever remains down, and strikes the shoulder of the "frog," the force of the concussion knocking off the loom by throwing the belt on to the loose pulley.

If this protector is not properly arranged it is liable to cause breakages. The crank shaft is stopped in the centre of its revolution, the other parts of the loom are also suddenly brought to rest, and as a consequence of the momentum which the various parts have gained a considerable liability to breakages is incurred.

The swords or arms of the lay are liable to break if the vertical distance between the stop-rod and the pin connecting the swords with the crank arms is too great. As regards liability of damage to the stop-rod itself, the nearer the "frog" is placed to the plane in which the stop-rod is moving the less the liability of damage to the latter. When the loom "knocks off" the belt should pass on to the loose pulley as quickly as possible. The "frog" is often made so that it will slide for a short distance on the loom frame when it is struck by the stop-rod lever, and it has also a projection upon it which is intended to strike the handle communicating with the belt fork, and at the same time to liberate the brake. If these parts are carefully adjusted the belt is actually upon the loose pulley and the brake fully applied before any concussion takes place in the various parts, even when a loom is running at a fair speed. This arrangement has a tendency to put more work upon the picking motion, for the shuttle must be thrown with sufficient force to enter the box and press back the spring. It must also be thrown at such a speed that it may reach the box in time to press back the spring and raise the lever catch to prevent knocking off at the time when the reed is at a sufficient distance from the cloth to avoid damage to the warp thread should the shuttle fail to reach the box.

CHAPTER VII.

DOUBLE, TREBLE AND TUBULAR WEAVING.

The Double Cloth Principle.—By the adoption of this principle a very wide fabric may be woven in a comparatively narrow loom. If a web 5 yards wide was wanted, a loom with at least 16 ft. of reed space would be required to weave it in the ordinary way, which would mean a very large and expensive loom. On the double cloth principle it may be woven upon a loom of only one-third that width, six threads being drawn through each split of the reed. If the cloth is to be a four leaf twill, for instance, twelve leaves of heddles will be required, as there will be in reality three webs of cloth on the one beam and each web requires four leaves. The web that is to be uppermost can be drawn on the four leaves that are next the lay, the centre web drawn into the four centre leaves and the under web into the four back leaves.

The first shot that is thrown is for the top web, the second for the centre web, and the third for the under web. If the first shot be thrown from the right hand, the top web will be joined to the centre one at the left hand, as the second shot must be thrown from the left, and the third shot being thrown from the right, the centre web and the under one will be joined at the right hand. The fourth shot is put through the under web from the left hand which forms the selvage for that side of the cloth. The fifth shot is put through the centre web from the right, and the sixth shot through the top web from the left and back again through the top web, thus forming the other selvedge. This operation is continually repeated until the web is completed.

It has already been explained how a four leaf twill is drawn and treaded, and the main thing to be attended to in drawing this web, is to draw each set the same as any other four leaf twill, taking one thread on each set alternately.

A barrel with 24 treads is thus required to work this cloth, as it takes six shots to make one repeat of the wefting and four shots to make one repeat of the twill, so that the product of the two is 24, the number of treads required. Arranged in this way, when the cloth is woven and taken off the loom, it will measure three times the breadth that it stands in, whatever that breadth may be. This might more properly be called treble cloth, as double cloth proper may be woven in a similar way with only two webs—an upper and a lower—joined together at one side, and with both selvedges at the other. Tubular goods such as sacks, hose pipe, &c., may be woven in a similar manner, there being no selvedge, however, both webs being joined together at both sides.

Seamless sacks may be made on the double cloth principle, joined together at one side forming the bottom, with both selvedges at the other side forming the lip and woven together for, say, 1 in., at each side, completing the bags, which are cut apart when the web is taken out of the loom.

CHAPTER VIII.

PRINCIPLES OF CLOTH CONSTRUCTION.

If the twill be considered as a plain figure it may be said that there are practically only two classes of linen and jute goods, *viz.*, plain cloth and figured cloth. Gauze and cross weaving is practically unknown in the trade. Plain cloth is formed by the warp and weft threads crossing each other at right angles, and passing under and over each other alternately. This is undoubtedly the very first principle in the construction of cloth, and that practised by the ancients before any attempt was made at ornamentation by forming patterns with the threads. Although this is the plainest and simplest make of cloth, by the use of combinations of colours it may be infinitely varied, and, as in jute carpets and rugs, beautiful effects produced in the simplest manner. Plain cloth is, for the strength and quality of material that may be put in it, the firmest and strongest of all makes.

Figured cloths cover a very wide range, although the principle is quite as simple in itself as plain. In figured cloth the pattern is formed by warp and weft threads, each passing over and under such a number of threads at a time as is necessary to form the pattern. The number of threads over or under which the warp and weft pass need not be limited or regular, it may be one or any number.

In one form of twill the warp and weft threads each pass alternately over and under three threads.

Another is a combination of the figure and the plain principle, for alongside a float three threads in length there are four ends which work plain, that is, the warp and weft threads pass under and over each other alternately.

In twills, the weft does not pass over and under the same sets of threads every time, but moves one thread to the right or left at every pick, thus forming a regular and continuous twill which is nothing more or less than a continuous figure.

In plain gauze or doup-weaving, between every pick of weft, the warp threads are made to cross each other, or, as it were, to twist half round each other, so that the weft threads are held separately, and a light, transparent fabric produced.

In designing textile fabrics, the first thing requisite is paper which is specially ruled for this purpose in small squares. The spaces between the lines, and not the lines themselves, are intended to represent the warp and the weft, the warp threads being vertical and the weft threads horizontal, the pattern being arranged by filling up the desired spaces representing the weft thread, passing over and leaving blank the squares which represent the warp threads under which the weft passes.

Plain cloth may be given a corded appearance if it is arranged that two warp threads work together as one through the piece, the cords running lengthwise with the piece. These cords will be made more distinct as the weft is made to preponderate in number of threads per inch over the warp. In a similar manner the warp threads may be made to work separately as in plain cloth, and the weft put in two picks as one, producing a cord running across the piece or in the direction of the weft. In a like manner a warp and a weft cord may be formed by three warp or three weft threads working together, or again, the cords may be of varying sizes, large and small alternately, consisting of one and three ends respectively, or the two cords may be combined, and a decided figure produced.

In combining two workings of this kind, as in other combinations, care and skill is required to join them so as to prevent an imperfection at the junction. Unsightliness may be obviated by so arranging the pattern that the first and last end or pick of each pattern becomes as much a portion of the pattern

to which it is joined as of the pattern to which it actually belongs, and forms part of both patterns. In this manner, and with care and ingenuity, a great variety of patterns may be produced upon the basis of plain cloth.

Next to plain cloth in its simplicity and extent of application comes twilling, or tweeling, which may be considered to be the first step in figuring. Twilled cloth is made for many purposes. It is the ground-work of many beautiful patterns in diaper and damask weaving. Three-leaf twills are greatly used for sheeting, bed tick, &c., while the twill used in jute sacking is known as a three-leaved regular twill. Herring-bone twill is used for bed tick. Four-leaved serge twill gives cloth having a similar appearance on both sides. Five-leaved twill is used in the manufacture of single damask table linen. In the weaving of fine and double damask cloths, the eight- leaved twill is employed.

Twills may be divided into three classes, *i.e.*, regular twills, broken or satin twills, and fancy twills. A regular twill approaches the most nearly to plain cloth. In this kind of twill the small stripes, formed by the intervals at which the warp and weft threads cross each other, run obliquely across the cloth, and are produced by the warp threads being raised in consecutive order, commencing at one side and following the direction the twill is intended to take. In the three-end twill every third end is raised or depressed in succession, the weft passing over or under the other two. This is done by having three healds, the warp being drawn through them, and the heddles raised to allow the weft to pass through in regular succession from front to back. The four-end twill is similar to the three-end twill, in this case the weft passing over or under three threads and is interwoven at the fourth. For this four leaves of heddles are required, the warp threads being drawn through and the healds raised in regular succession as before. Twills of five, six, or more ends may be worked in a similar manner, the number of threads in

the twill being drawn on a corresponding number of leaves of heddles and raised in consecutive order. It is not necessary that regular twills should be confined to one thread rising or sinking at once, but any number into which the pattern may be divided may be raised or depressed together.

Twilled cloth does not possess the same wearing qualities as does plain cloth, for in making plain cloth every thread is alternately interwoven, while in twills the threads are only interwoven at intervals. In the latter case the threads have no support from each other, except where they are caught by the weft, and that part of them which is flushed must depend upon the strength of the individual threads, those of the warp being flushed upon one side, and those of the weft upon the other. Twilling may give weight to the cloth, for by twilling a greater number of threads per inch, both in the warp and weft, can be put in than can possibly be put into plain cloth, the character of the working allowing the threads to lie closer together, and consequently produces a stouter fabric. The larger the twill is, the heavier the cloth can be made, for when the shed is open, every thread of warp, either above or below the thread of weft, will oppose a certain resistance to the operation of weaving. Now in plain cloth every thread is alternately interwoven, and therefore opposes its proportion of resistance, whereas in a six-leaf twill, for instance, every sixth thread only is intersected, and it will easily be seen that less resistance will be given to get the weft on.

In nearly all twills, one great object aimed at is clearness and closeness of the twill, so that the cloth may look as fine and compact in its structure as possible. To attain this result, the direction of the twill must be determined by the twist of the weft and warp, and should run in a direction contrary to both. The result of this arrangement is that each thread of warp or weft in forming the twill becomes partly embedded over or under its immediate neighbour, and

so produces a closeness and fineness which could not be obtained by any other means.

In a three-leaved twill, two-thirds of the warp is on one side of the cloth and two-thirds of the weft upon the other. This is accomplished by sinking two leaves and raising one every shot. The warp is drawn through the heddles as follows: One thread through the first or front leaf, one thread through the second leaf, and one through the third or back leaf. In forming the first shed the first and second leaves are depressed and the third is raised. For the second shed the first and third leaves are depressed while the second is raised, while for the third shed the second and third leaves are depressed and the first raised, this cycle being repeated.

To make what is called a herring-bone twill, with three leaves, the same treading as above will do, but the draught will be as follows: Suppose the cloth is for bed tick, and the pattern twelve of blue and twelve of white. Then the web must be drawn with six threads of blue drawn through the heddles, beginning with the first leaf, and six threads beginning with the third, and the white drawn in the same manner; or, better still, so that the twill may turn upon one thread instead of upon two, which does not make the herring-bone so neat, the warp may be drawn with ten threads of blue and ten threads of white.

A four-leaf twill may either be drawn straight over or through a heddle on each leaf alternately. When it is drawn straight over, the first shed is formed with the back leaf up and the other three down; the second with the third leaf up and the other three down; the third with the second up and the other three down; and the fourth with the first or front leaf up and the other three down.

When a four-leaved twill is drawn through a heddle in each leaf alternately, which is the usual way, either plain or twilled cloth may be made with the same drafting, it being merely necessary to fix the two front leaves together as one,

and the two back ones together as another, to make plain cloth. In this plan the treading for twilling is different, however, the fourth leaf being first raised, then the second, then the third, and last of all the first or front leaf.

A very large quantity of cloth is made by a four-leaf twill, where the warp and weft are equal on both sides of the cloth by sinking two leaves and raising two alternately.

Plain and twill may be combined to produce a pattern which will give a firmer texture to the cloth, which will have the character of a plain cloth with a twill pattern upon it. A fabric of this description may have three of five threads working plain, the weft passing over or under the other two to form the twill. Or the pattern may be composed of six threads, three plain and three forming a twill. If patterns in which the twill is formed by the weft passing under and over a regular number of threads in regular succession be combined with patterns in which the twill is formed by a number of plain ends and intervals of warp over or under which the weft passes, beautiful and elaborate patterns, to the extent and variety of which there is scarcely any limit, may be produced.

Diaper weaving is largely used in the manufacture of towelling and tablecloths. The form of diaper known as Irish eye is one of the best for nursery diapers, &c. It is a three-leaved diaper, with two-thirds of the weft thrown to the one side of the cloth, and two-thirds of the warp to the other. Four-leaved diapers have the warp and weft equal on both sides, which makes by far the best bird's-eye diaper, although the three-leaved one looks much finer, if they are both woven in the same set of reed, and both have the same quantity of shots on the glass.

The form of diaper which is called diamond draught requires eight different treads to complete the pattern. For high-class linen towelling, when a large diaper pattern is required, a seven-leaved diaper with twelve treads, or an eight-leaved diaper with fourteen treads, may be employed.

CHAPTER IX.

WEAVING CALCULATIONS.

There are several systems of numbering or indicating the grist or counts of linen and jute yarns. The English and Irish system of numbering linen yarn is based upon the number of "cuts" or "leas" which go to weigh 1 lb. avoirdupois, while the basis of the Scotch system of numbering linen and jute yarns is the weight in pounds of forty-eight cuts or leas, which are called a spyndle or spangle. It will thus be noticed that under the Irish system the higher the counts the finer is the yarn, while under the Scotch system it is the reverse. This simply arises from the fact that under the Irish system the counts are indicated by the number of leas which weigh a given weight, and consequently the more hanks are required to be equal to that weight the finer the yarn must be, whereas under the Scotch system the counts are indicated by the weight of the spyndle, and consequently the higher the counts the more the spyndle weighs, and therefore the heavier is the thread.

The length of a lea or cut of linen or jute yarn has been fixed by law at 300 yards.

Irish counts of linen yarn may be reduced to their equivalent under the Scotch system by dividing the Irish counts into the number 48. Thus 6-lea linen counts $\frac{48}{6} = 8$ lb. Scotch yarn and *vice versâ* Scotch counts may be reduced to their equivalent Irish counts in the same manner, for 12 lb. Scotch yarn is equal to $\frac{48}{12} = 4$ lea Irish. Thus:—

1 lea Irish	= 48 lb. Scotch.	4 lea Irish	= 12 lb. Scotch.
2 ,, ,,	= 24 ,, ,,	8 ,, ,,	= 6 ,, ,,
3 ,, ,,	= 16 ,, ,,	12 ,, ,,	= 4 ,, ,,
6 ,, ,,	= 8 ,, ,,	16 ,, ,,	= 3 ,, ,,

(and so on.)

The Dorset and Somerset system of yarn numbering, used in the West of England sailcloth works, is based upon the weight, in lb., of a "dozen" containing 21,600 yards or 12 half-hanks. Eighteen lb. Somerset yarn is thus equal to 12 lb. Scotch. Scotch counts may be reduced to Somerset numbers by multiplying by 3, and dividing by 2.

The English or Irish yarn table, which is almost universally accepted among wet spinners at home and on the Continent, is as follows, the yarn number being equal to the number of cuts per lb. :—

Yards	Threads	Cuts or leas	Hanks	Bundles
$2\frac{1}{2}$	1	0	0	0
300	120	1	0	0
3,600	1,440	12	1	0
60,000	24,000	200	$16\frac{2}{3}$	1

The yarn table as used in the Scotch jute and dry spun linen yarn trade is as follows, the yarn number being the weight in lb. of a spyndle or spangle :—

Yards	Threads	Cuts	Heers	Hanks	Hesps	Spyndles
$2\frac{1}{2}$	1	0	0	0	0	0
300	120	1	0	0	0	0
600	240	2	1	0	0	0
3,600	1,440	12	6	1	0	0
7,200	2,880	24	12	2	1	0
14,400	5,760	48	24	4	2	1

A Belgian paquet is equal to 3 English bundles, and a French paquet to 6 English bundles. The Austrian yarn table as used in the Trautenan district is as follows, the yarn number being equal to the number of hanks required to weigh 10 lb. :—

Threads	Cuts	Hanks	Pieces	Bundles	Schock
60	1	0	0	0	0
1,200	20	1	0	0	0
4,800	80	4	1	0	0
24,000	400	20	5	1	0
288,000	4,800	240	60	12	1

A very important factor in the structure of cloth is the

diameter of the threads used. In connection with this it must be borne in mind that the diameters of threads vary as the square roots of their counts, and not directly as their counts, as some might suppose.

The important subject of "setts," or the method of indicating the pitch or fineness, or distance apart, of the warp threads of which a piece of cloth is composed, has been already discussed. These threads are separated or distributed by the reed or sley, and consequently the term "sett of the reed" is commonly employed, and simply means the number of threads in a given space in the cloth, as the number per inch or to any other unit of measurement.

Particulars already given as to counts of yarn and setts are required for determining the weight of warp or weft contained in a piece of fabric, and also for determining the cost.

The next question to deal with is, then, the weight and cost of the warp and weft, beginning first with the calculation for finding the weight of a warp when the number of ends and the length are known. The number of cuts or leas must first be found by multiplying the number of ends in the warp by the yards in length and dividing by 300, the yards per cut or lea. This having been ascertained, the weight in lb. of the warp is found by dividing by the counts or lea of the yarn.

In a similar manner the number of spyndles or spangles of 14,400 yards each in the warp may be found if Scotch yarn is being used. The number of spyndles multiplied by the pounds per spyndle or the Scotch counts will give the weight of the warp.

If it is desired to use a certain weight of warp and a certain sett, and it is required to find what Irish count of yarn is required to produce that weight, the number of ends in the warp must be multiplied by the length of the warp in yards, and the product divided by 300 and by the weight of the warp.

To find the Scotch number which will be required to produce a warp of a given length, number of ends, and given weight, multiply 14,400 yards per spyndle by the weight of

the warp in pounds, and divide by the length of the warp in yards multiplied by the number of ends.

When weight, counts, and ends are given to find length, or when weight, counts, and length are given to find ends:

This question arises when there is a certain weight of material which must be used up, and it is desired to make a warp which shall use this material with a certainty that there shall be none left. One of two conditions may attach to this —first, the weights and counts being known, it is desired to make a warp of a given length, and the number of ends which such warp will contain is required. Second, the weight and counts of the yarn being known, it is desired to make a warp containing a given number of ends, and the length of warp containing such number of ends which the material will make is required. The first condition is somewhat analogous to that previously pointed out, where a given weight of material is to be employed to produce a cloth, differing from it in respect of both weight and counts being known instead of only weight being known.

For the first of these conditions the rule for Irish yarn is: Multiply the weight of yarn by its counts and by 300 and divide by the yards of warp required.

Example: It is required to make 10 lb. of 40^s lea yarn into a warp 60 yards long; how many ends will it contain?

$$\frac{10 \times 40 \times 300}{60} = 2{,}000 \text{ ends.}$$

In the second case, where the ends are given and it is required to find the yards, substitute ends for yards, or—

Multiply the weight by counts and by 300 and divide by the number of ends; the quotient will be the yards.

Example: It is required to make 10 lb. 40-lea linen yarn into a warp containing 2,000 ends; how many yards long will the warp be?

$$\frac{10 \times 40 \times 300}{2{,}000} = 60 \text{ yards long.}$$

If the weight and lea of the warp yarn to be used are given, together with the length of the warp and the width in the reed, and it is required to find the sett of the necessary reed

in porters or beers, of 20 dents each, on 37 in., the product of the weight of warp, lea, yards per lea (300) and 37 must be divided by the product of the length of the warp in yards, width of reed, and 40 ends per porter or beer.

To ascertain the cost of a warp there is little to do after the weight is found, the price per lb. being known, the weight multiplied by that price of course giving the total cost.

Weft calculations are made in a very similar manner. If, for instance, a piece of cloth is to be produced of a given width and with a given number of weft threads per inch, and it is required to find what length of yarn will be required to produce a given length of cloth, the width of the piece must be multiplied by the picks per inch, and the product will be equal to the inches of yarn contained in one inch of cloth, and consequently to the yards of yarn in one yard of cloth. This product multiplied by the yards in the piece will, of course, give the yards of weft required to complete the piece.

Example.—A cloth is 40 in. wide and has 30 picks per inch; what length of weft yarn does one yard of cloth contain? Answer: $\frac{40 \times 30 \times 36}{36} = 1{,}200$ yards.

The length of weft yarn required for 50 yards of cloth, for instance, will of course be fifty times this, and so on. The number of spangles of yarn required for 50 yards of the above cloth will be $\frac{1{,}200 \times 50}{14{,}400} = 4$ spangles 8 cuts. The number of bundles required will in like manner be $\frac{1{,}200 \times 50}{60{,}000} = 1$ bundle.

The weight of weft is also easily found from its length if the lea of the yarn used be known. Thus, 4 spangles and 8 cuts of 4-lb. or 12-lea yarn will weigh $4 \times 4\frac{1}{6} = 16\frac{2}{3}$ lb. or $\frac{200}{12} = 16\frac{2}{3}$ lb.

In these calculations no allowance has been made for shrinkage or waste of yarn while weaving. No fixed allowance for shrinkage and waste can be made, as so much depends upon the quality of yarn, the pattern, and picks per inch. The best way is to make the calculations on the basis of the actual width of the cloth, or on the width in the reed and the actual length of cloth, and then to add such a

percentage for shrinkage, waste, &c., as experience teaches to be sufficient; by this means more accurate results will be obtained than by any attempt to work by a fixed rule.

Sometimes it may be required to use up a given quantity or weight of weft, and it is required to find what number of picks per inch must be put into a piece of given length and width. To solve this problem the quantity of weft in hanks must be multiplied by 3,600, the yards per hank, and the product divided by the length and width of the piece.

For instance, it may be desired to use up 10 spangles of weft in a piece 150 yards long and 30 in. wide. What number of picks per inch of weft must the cloth contain? Answer: $\frac{10 \times 4 \times 3{,}600}{150 \times 30} = 32$.

Again, if cloth of the same length and width is to contain 8 spangles of 6-lb. weft, or 48 lb. of weft, the number of picks per inch which must be put in will be $\frac{48 \times 2{,}400}{150 \times 30} = 26$ nearly.

It will be seen that in these calculations the object aimed at is to ascertain the total number of yards of weft to be used, then to divide by the length of the piece in yards, giving the length of weft yarn in one yard. This divided by the width of the piece must necessarily give the number of picks or threads of weft per inch.

To find the width or length of a piece which will contain a given quantity of weft, the picks per inch being known.—Rule: If the width is given, multiply the quantity in hanks, bundles or spangles by the yards per hank, bundle or spangle respectively, and divide by the picks per inch and by the width in inches. If the length is given, substitute length for width as a divisor.

Example.—A piece having 30 picks per inch must contain 18 hanks of linen yarn. The width being 36 in., what length of piece will it make? Answer: $\frac{18 \times 3{,}600}{36 \times 30} = 60$ yards.

The question of cost of weft, as of warp, is of course easily found by multiplying the quantity or weight contained in the piece by the rice per bundle, spangle, or lb.

CHAPTER X.

AUTOMATIC LOOMS, STOP MOTIONS, &c.

THE aim and object of automatic looms is to diminish the labour and attention required on the weaver's part, and thus to enable him or her to attend to a larger number of looms. Since a large part of the weaver's work on the ordinary loom consists in refilling and re-threading the shuttle when the weft breaks or runs out, the leading feature of automatic looms is the automatic supply of fresh weft to the loom on the exhaustion or failure of the supply. In this way the weaver has time to attend to a very considerably larger number of looms. The fact that the weaver does look after a large number of looms entails the necessity for a warp stop motions, lest fault in the cloth should be produced by broken warp threads running for a considerable time. As linen warps are inelastic and frequently brittle, automatic looms are not nearly so common in the linen and jute trades as they are in the cotton trade, and when they are used in the former trade it is generally upon union cloths with cotton warps.

There are two types of looms in which the weft is automatically replenished. In one, fresh shuttles, filled in the usual way, are automatically supplied from a magazine. In the other type the shuttle is not changed, but the spent pirn or cop is pushed out and another forced in to take its place, the shuttle being made in such a way that it re-threads itself. The Northrop loom, shown in fig. 20, is representative of the latter type, and the Hattersley self-shuttling loom, represented in fig. 21, of the former type.

The Northrop loom possesses, in addition to the shedding, picking and beating-up mechanisms of the power loom, a battery, warp stop motion, feeler and thread-cutting motion, and warp let-off motion. The magazine or battery for holding the reserve of weft cops or pirns ready for transference to the shuttle consists of three principal parts, namely, (1) the battery frame, a circular casting of substantial proportion, firmly affixed to the right-hand side of the breast beam, and

FIG. 20.—Northrop Linen Loom.

of such construction that its bottom centre extends directly over the shuttle-box when the slay is fully forward; (2) a disc, carried on a shaft fixed to the centre of the battery frame, round the periphery of which disc are thirty cup-shaped notches intended to receive the butt or base of a cop skewer or pirn. At a correct distance from this disc is placed a flange, having suitable springs which come directly opposite and support the end of the pirn or cop. The ends of the weft threads extend from the weft holder over a guide, and are

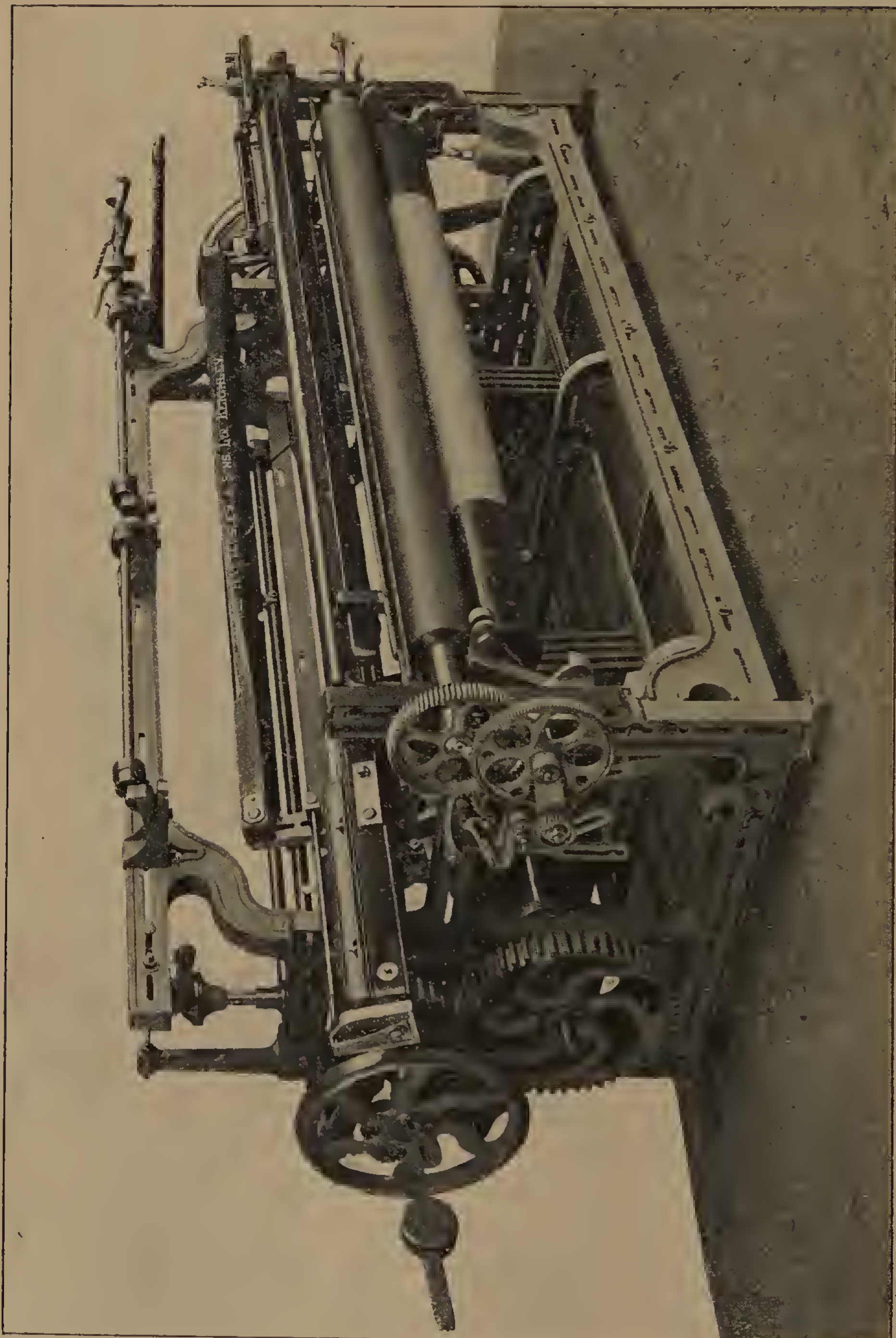


FIG. 21.—Hattersley Self-shuttling Loom.

wound round a stud. The weft carriers with their disc are free to revolve on the shaft and come in succession under the face of a "transfer hammer" or bell crank lever, worked from a movable contact, which, on the exhaustion of the weft, through connection to the weft fork, is brought into the path of a projecting catch on the slay, imparting a downward circular motion to the transfer hammer as the shuttle-boxes come beneath the battery, a full pirn or cop being forced downwards into the shuttle, thrusting out the empty pirn or cop skewer at the bottom, causing it to fall into a box fixed for its reception.

The warp stop motion controls the warp threads and stops the loom immediately a thread breaks. It may be briefly described as follows: It consists in the use of thin steel drop wires some 3½ in. in length, each suspended by a warp thread passing through a round eye in its centre, and having a slot above through which is passed a flat bar, keeping the drop wires in position in the warp stop-box. At the bottom of this box is a serrated vibrator moving with a reciprocating motion from a simple eccentric on the tappet shaft. The breaking of the warp threads allows a drop wire or detector to fall in the path of this vibrator, and immediately puts in action a knock-off finger in contact with the starting handle. When the set of the reed and the counts of the yarn are such that the warp is crowded, a motion having the detectors arranged in four rows is adopted so as to evenly distribute them and allow of their more efficient working. A feeler and thread-cutting motion is also provided. The former controls the weft in the shuttles and compels a fresh supply to be inserted before the weft yarn is completely exhausted. The object of the latter is to cut and take care of the loose end of weft from the selvedge to the battery end. These two combined are intended to ensure perfect cloth.

A warp let-off motion controls the letting off of the warp from the yarn beam automatically. The production is about

the same as with an ordinary loom, but the weaver attends to a greater number of looms.

Fig. 20 shows the Northrop loom model H, with special framing, 45 in. R.S., special breast beam and linen let-off motion for weaving linen union cloths.

The Hattersley self-shuttling loom (fig. 21) is really an ordinary one-shuttle loom which automatically stops on failure of the weft, ejects the spent shuttle, replaces it with a full shuttle and re-starts the loom. As will be seen from the illustration, the loom is provided with a hopper containing a number of shuttles provided with cops or pirns in the ordinary way. This hopper or magazine is secured in a fixed position on the breast beam, opposite to the box on the lathe. On the failure of weft the loom is stopped by means of the weft fork, the shuttle being brought opposite to the magazine when the loom comes to a stop. The driving belt of the loom, through the medium of the ordinary loose pulley, brings into action a pap-wheel, on the low shaft of which are four tappets, which respectively communicate with mechanism which raises the front of the shuttle-box, ejects the spent shuttle, places a full shuttle in the box, and re-starts the loom. All these motions are carried out quite automatically, and without any attention from the weaver beyond keeping a constant supply of shuttles in the magazine, and placing the end of the weft from the cop or pirn in each shuttle in a clip, so that when a full shuttle is being exchanged for an empty one, the end of the weft will be held whilst the shuttle is picked for the first time. Thus the mechanism takes the place of the weaver, and automatically performs the same operation that she would perform in introducing a fresh shuttle in the loom, but does it considerably quicker than the most expert weaver could. The arrangement entirely prevents thick or thin places in the cloth, the worst fault that can occur being two picks of weft in the same shed part way across the piece. In order to prevent even this defect the motion may

be so arranged that when the weaver sees that the weft in the shuttle is nearly exhausted, she touches a button, and the shuttle is automatically ejected and replaced by a full shuttle from the magazine, and the loom is automatically re-started. If the weaver fails to notice that the weft is nearly exhausted, the loom will in this case stop on the failure of the weft, and must be re-started in the usual way. Or, as in the Northrop loom, a weft indicator or feeling motion may be provided both for the automatic and semi-automatic looms. This mechanism is arranged to constantly feel at the cop or pirn near the end, and when only a few yards of weft are left, motion is transmitted to the usual stop motion, the shuttle ejected, a fresh one supplied, and the loom started again. The self-shuttling motion operates exceedingly well. An advantage is claimed over the Northrop loom in that the loom comes to a dead stop for the change of shuttle, preventing undue wear and tear to the change mechanism. There are stronger and fewer working parts, which require but little more attention from the tenter than in the ordinary loom. The usual reeds, healds, shuttles, pickers, &c., are used. Further, any kind or size of weft pirn or cop may be used. As the change of shuttle is effected in two and a quarter seconds, the time spent in re-shuttling is less than five minutes per day on the average, and the production only 2 per cent. less than if the loom had not been stopped for re-shuttling.

The jute or hemp loom has a shuttle-box which admits a shuttle taking a cop 10 in. long by $1\frac{3}{4}$ in. diameter. On the failure of the weft, the loom is stopped by the weft fork, the loose pulley bringing into action a pap-wheel, on the low-shaft of which are fixed four tappets, which respectively raise the front of the shuttle-box, eject the spent shuttles, place the full shuttle in the box and restart the loom. The take-up motion is positive, with heavy wrought iron take-up beam, turned true, and covered with filleing; a change wheel determines the number of picks per inch. An auxiliary negative

motion winds the cloth on the cloth beam, or, if preferred, a positive take-up motion can be applied. The let-off motion is clamp friction, controlled by weights and applied by wood friction blocks to large hoops secured to a steel tube warp beam. This loom admits of warp beam flanges up to 26 in. in diameter. The warp beam can be reversed by the weaver when at the front of the loom. This reversing motion consists of suitable levers and gearing so arranged that the weight may be taken off the beam and the warp rewound on the same. A 67-in. R.S. loom is often run at 125 picks per minute, weight 25 cwt., and measures 10 ft. 9 in. by 5 ft. 6 in. over all.

CHAPTER XI.

FINISHING.

Linen woven from grey or unbleached yarns is called brown linen. Brown linens not sold in the brown state are sent to the bleacher to be bleached and then finished by him, or bleached simply and then sent to the dyer or printer to be coloured first and finished afterwards. A large quantity of the low-priced linens made are exported in the brown state. Some are merely boiled or soured to give them a lighter or yellower shade, and some are dyed slate colour, but the greater portion of linen goods are bleached. Some of the bleached cloth is printed for dresses, handkerchiefs, &c., and very beautiful products they are.

Before leaving the factory, the linen cloth is first looked over by the cloth-passer and then run through the cropping machine (fig. 22), in which spiral knives shear any knots and loose threads from the surface of the cloth.

Ireland possesses the best climate in the world for linen bleaching, and it is this gift of Nature which has given her so high a position in this branch of industry.

The word *bleaching* comes from the French *blanchir*, to whiten. The processes employed for bleaching linen are much more difficult and tedious than those for bleaching cotton fabrics, for linen contains much more colouring matter than cotton, and loses nearly one-third of its weight in the bleaching process, while cotton only loses one-twentieth. There are two systems of bleaching, the old and the new; the distinguishing feature of the first being *crofting*, and of the latter *chemicking*. In both systems, *bucking* and *souring* are employed. *Crofting* is a tedious

process, consisting in exposing the linen for two or three days at a time to the action of the atmosphere, spread upon the grass of the bleachfields. The crofting is repeated at frequent intervals, about half the time employed in bleaching being devoted to it. *Chemicking* consists in steeping the cloth in a solution of chloride of lime. The cloth is placed in stone vats, over the centre of which a perforated trough is suspended. Into this the solution is pumped, and from it pours down upon the cloth. The process is continued for about four hours.

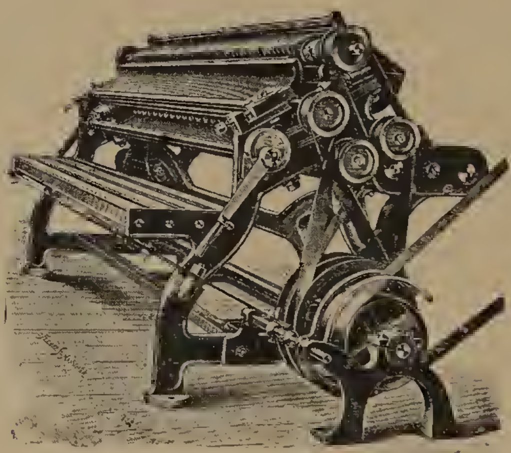


FIG. 22.

The bleaching powder, in order to be applied to the cloth, must be dissolved in water in the proportion of about half a pound of chloride of lime to three gallons of water. This quantity of chloride of lime steep or chemick will bleach one pound of linen.

Bucking consists in boiling the cloth in alkaline lye, or in slaked lime first and alkaline lye afterwards, in large iron keirs or boiling-pots for eight to ten hours at a time. This operation is repeated very frequently in the open-air method of bleaching, and is always followed by crofting or grassing. *Souring* is the process of steeping the cloth in water mixed with

sulphuric acid in the proportion of 8 gallons of the latter to 200 of the former. The cloth is allowed to remain in the sour for about ten hours. As the acid is most injurious if allowed to remain in the cloth, every trace of it must be removed by very careful washing. Besides whitening the cloth, the sour removes the lime and alkali. As many as twenty-two operations, or, including the intermediate washings, forty-four operations have been employed under the old system for bleaching a parcel of linens. Thirty-one days were required to complete the process, thirteen of them being devoted to crofting. The new method consists of only about thirteen operations and occupies a much shorter time, but is apt to "tender" the cloth.

If the bleached linen has to be dyed or printed, it is sent to the dye or print works in an unfinished state.

If the linen is to be finished by the bleacher, he first starches it. The starch is made from wheat flour and mixed with a little indigo to give it a blue shade, and with a sufficient quantity of water to give it the desired consistency. Fine clay, gypsum, Spanish white or sulphate of baryta are sometimes added to the starch to give weight to the cloth. The starch is placed in a trough, through which a roller draws the cloth with the starch regularly and evenly laid on. The other rollers of the starching machine (or stiffening mangle) squeeze out the superfluous starch, which falls back into the trough. After the cloth has been starched, it is dried upon steam-heated tin or copper cylinders or cans, or by a strong current of heated air blown upon it as it is stretched upon the stentering machine. The cloth is now ready for the finishing process proper, which, in the North of Ireland, consists in "beetling it." The beetling engine consists of a number of wooden stocks falling upon a smooth, strong, wooden roller which revolves very slowly. The beetles are lifted and then allowed to fall by pieces of wood which project from a revolving beam behind the machine and engage with corresponding pieces in the stocks.

In Scotland few linen goods are now put upon the market without undergoing some process of calendering, as this process greatly improves the appearance of the fabric without injuring its quality. The cloth is slightly damped before being passed through the calender. The damping machine (fig. 23) is fitted with a box, partly filled with water, within which a circular brush revolves at a high speed, just touching the surface of the water. The cloth is drawn over the mouth of the box by a pair of rollers worked by machinery. In its progress it is sprinkled by the brush with a fine spray, which deposits a number of small round wet spots on its surface. The cloth is

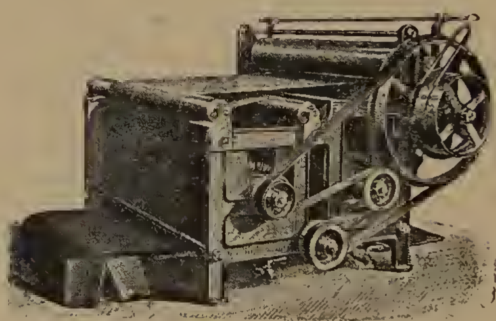


FIG. 23.

plaited down as it is given out by the rollers and allowed to lie for some time, when the spots disappear and the cloth becomes uniformly damp.

The object of calendering or cylindering is to impart a soft gloss to the cloth. This is effected by passing it over and under rollers, pressed together by considerable pressure, which varies according to the degree of finish desired. The rollers, or bowls, to the number of four, five or six, are placed one above the other in a massive iron framework as shown in fig. 24, and consist of cast iron, wood, and compressed paper. The cloth is first wound upon a wooden bowl near the ground; it is then passed round a hollow iron bowl, then round a paper

one, and then under a very heavy cast-iron bowl, to be finally wound upon a wooden roller. The cast-iron bowls can be heated by steam. The pressure is applied to the bowls by means of hand wheels, screws and levers. Different styles of finish may be given to the goods by putting them through between the rollers in particular ways, and the goods are said to have been sarceneted, cylindered, chested or mangled, as the case may be.

In most of the calendering processes, the cloth is slightly contracted in width and increased in length.

The finished cloth is then measured and lapped or made up

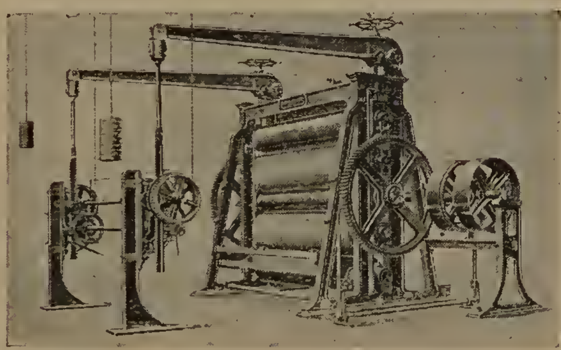


FIG. 24.—Calendering Machine.

to suit the special taste of the market for which it is intended, then packed and shipped. Linen for the home trade is generally folded in thick pieces, each containing 25 to 30 yards, and plainly ornamented with fancy ribbons and devices. Linen for export is much more profusely ornamented ; tickets with devices in gold and bronze upon a blue or red ground are pasted on, presenting a very gay appearance, and mottoes denoting the locality from which the style was derived are impressed upon the cloth or tickets. Almost every country has a special "fold" peculiar to itself, which alone will sell there. Cambric handkerchiefs and other high-class goods are

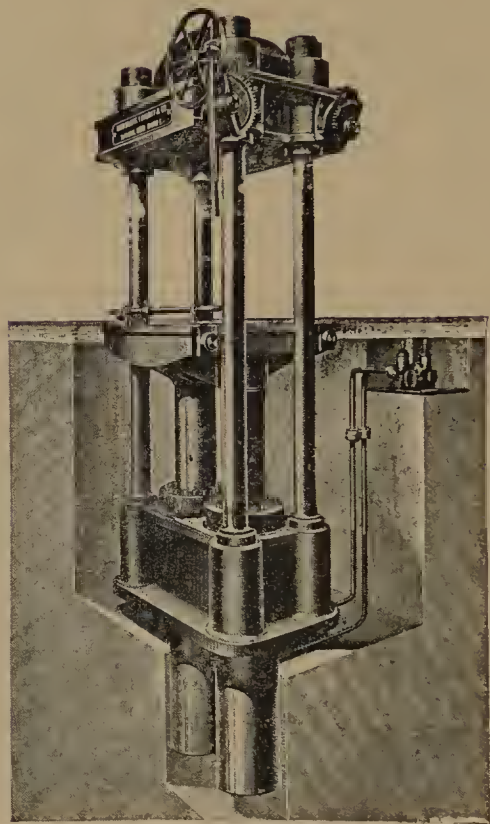
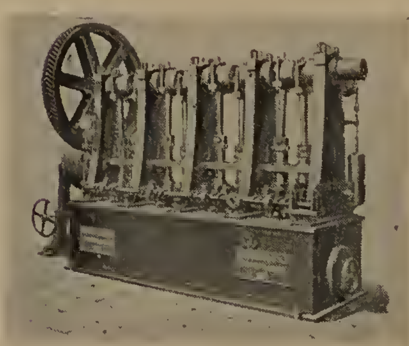


FIG. 25.



often put into elaborately-made boxes, having a most attractive appearance when displayed to advantage in shop windows.

When the pieces have been folded and ticketed, they are placed in a hydraulic press with a piece of pasteboard between the pieces. Hydraulic packing presses, as shown in fig. 25, are powerfully constructed and capable of exerting a pressure on the bales of from 10 to 100 tons and upwards. After being pressed, the pieces are packed in wooden boxes, which are then securely nailed down, hooped, and marked ready for delivery.

CHAPTER XII.

THE CONSTRUCTION, VENTILATION AND HUMIDIFICATION OF THE WEAVING SHED.

Linen and jute weaving sheds are almost invariably built with saw-tooth roofs, about 12 ft. to the gutter. This type of roof is adopted as the only practical way of getting a good light in a building covering a large area, for if the bays run east and west, and the skylights face the north, a good north light is obtained and the direct rays of the sun eliminated.

Ventilation is necessary to conform with the requirements of the Factory Act, which specifies that "during working hours the proportion of carbolic acid in the air of the room shall not exceed 20 volumes per 10,000 volumes of air at any time when gas or oil is used for lighting or within one hour thereafter), or 12 volumes per 10,000 when electric light is used (or within one hour thereafter), or 9 volumes per 10,000 at any other time."

We have previously drawn attention to the advantage of a humid weaving atmosphere, especially in weaving fine cloth and when dressed warps are used, for if the air is dry the yarn becomes brittle and breaks, frequently producing inferior cloth and reducing production. A humidifying system should be employed which is capable of giving cold damp air in summer and warm damp air in winter, for the old system of "steaming" is out of date and injurious to the health of the workers. The humidifier should give just the right degree of humidity to the atmosphere without involving the risk of drops falling upon the cloth and looms below, and should at

the same time give adequate ventilation to keep the proportion of carbonic acid below the amounts specified above. The water should be reduced to an exceedingly fine state of division, more like mist or fog than spray, and the atmosphere for each particular process should be so arranged and maintained as to give the best possible conditions all through the year, irrespective of the outside atmospheric conditions. Such results are produced by the Kestner system, by means of which the best conditions of temperature, humidity, and purity may be secured.

Fig. 26 gives the general appearance of the "Kestner" plant. K is the special atomizer fan by means of which the water supplied is pulverized into minute atoms which are naturally absorbed by the air as it passes through the fan. S is the suction duct through which the fresh air is drawn from the outside of the buildings by the fan. V is the inlet for fresh air. B is the water separator or trap. R and RI are the return water-pipes. D is the distributing duct. G is the deflector trcugh to deflect the air issuing from the duct D upward and so avoid causing draughts.

The apparatus acts as follows: Fresh air is drawn from the outside of the room through S and sucked into the fan. Water is fed into the fan and "atomized" in the fan-wheel and absorbed by the air passing through, which is washed and thereby purified and cooled. This conditioned air is then delivered along the duct D and distributed into the room through the trough, which gives equal distribution along the whole length, and deflects the air slightly upwards, enabling it to carry well into the room, prevents draughts, and secures thorough impregnation. To humidify and purify the entering air, a water-pipe is led from the usual service to the fan K which is fitted with a special atomizing device of simple construction, containing no small holes to make up. The plant is designed to give an air supply sufficient to put the room treated under a pressure or

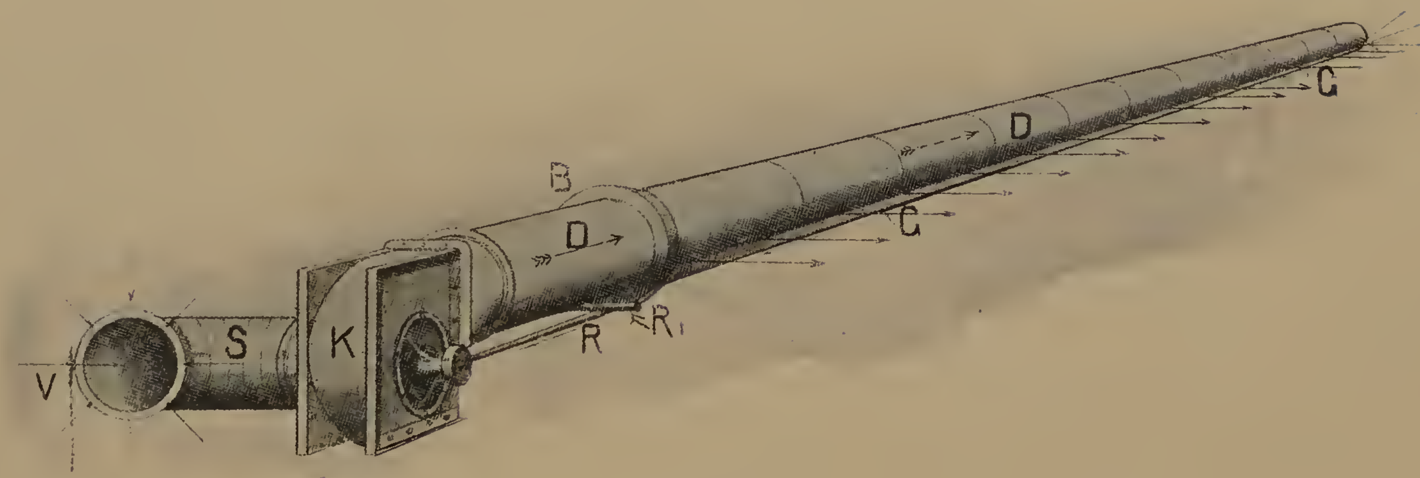


FIG. 26.

plenum, thus promoting an even distribution of humidity over the whole room and preventing the entry of air from outside.

Fig. 27 shows a usual arrangement of the plant, but in weaving sheds it is generally more convenient to bring the fresh air inlet-pipe through the roof. In all cases each apparatus is complete in itself, and may be worked quite independently.

The purification of the air is thoroughly carried out by the Kestner system, as, owing to the complete atomization of the

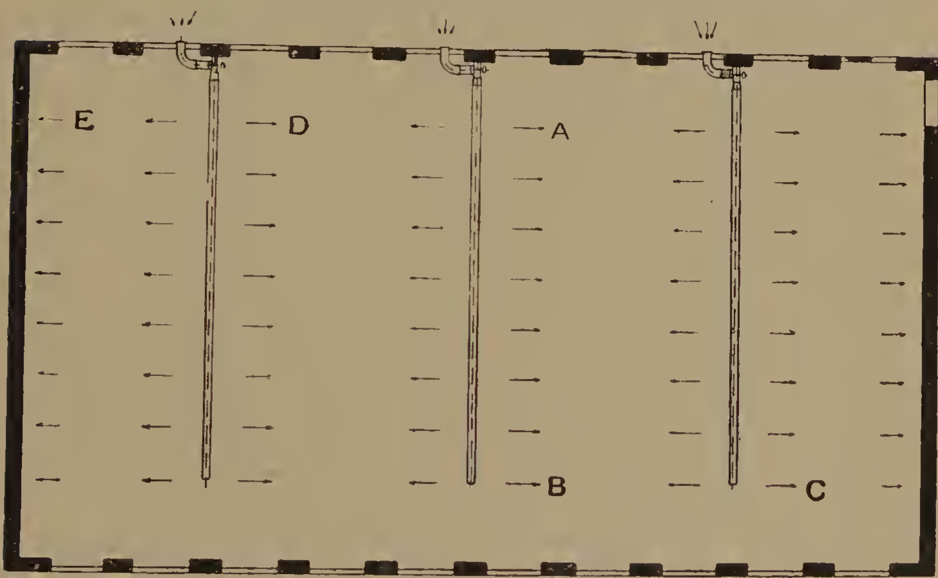


FIG. 27.

water, the air is brought into more intimate contact with it and for a longer period than can be done by any other system, one result being that all impurities, including "blacks" and "smuts," are entirely eliminated, and the amount of carbonic acid may be kept, if required, as low as that in the outside atmosphere, the requirements of the law as to purity being more than complied with.

Another advantage is that the water vapour is thoroughly combined with the air, and not merely sprayed into it, thereby securing any necessary degree of humidity, equally distributed,

even during the driest periods, or at any temperature. In addition, owing to the thorough manner in which the air is washed, and its complete admixture with the water during the process of atomization, the cooling effect is very considerable; in fact the air is brought down to almost the same temperature as the water in some cases.

If required in cold weather, however, the entering air may be warmed to any extent, and in some cases this plant alone is used to warm sheds, no steam-pipes or other appliance being fixed. A perfect hygienic weaving atmosphere may be always secured, and the maximum output of well-made cloth attained. Besides these advantages the workpeople are enabled to breathe pure wholesome air, cooled or warmed to the most suitable temperature, the result being that they are able to exert the maximum of effort with the minimum of fatigue, are better able to resist illness or disease, and are kept in more robust health.

The Factory Act provides that " in every room in which artificial humidity of air is produced in aid of manufacture, a set of standardized wet and dry bulb thermometers shall be kept affixed in the centre of the room, or in such other position as may be directed by the Inspector. Each of the above thermometers must be read between 10 and 11 a.m. on every day that any person is employed in the room, and again between 3 and 4 p.m., and each reading at once entered upon a prescribed form. The form must be hung up near the thermometers to which it relates, and must be forwarded, duly filled in, at the end of each month to the Inspector."

This regulation does not apply to any room in which the difference of reading between the wet and dry bulb thermometers is never less than 4 degrees, if notice of intention to work on that system has been given to the Inspector.

It is further stipulated that " the humidity of the atmosphere of any weaving shed shall not be such that the difference between the readings of the wet and dry bulb thermometers is less than two degrees."

The wet and dry bulb thermometers referred to constitute a hygrometer. Each bulb thermometer is carefully graded on its own separate stem. The wet bulb is covered with a small piece of muslin, which is kept moist by connection with a small reservoir of clean soft rain-water (or distilled water) directly underneath. Both thermometers are mounted independently, and the temperatures of air and evaporation are given by the direct readings of both. By comparing these readings with the following table, the percentage of humidity is ascertained.

HUMIDITY TABLE FOR ATTAINING GOOD RESULTS AT TEMPERATURES VARYING FROM 100° TO 40° F.

Dry bulb. °	Wet bulb. °	Relative humidity. Per cent.	Weight of vapour in grains.
100	85·5	46	9·2
99	84·0	46	9·0
98	83·6	47	8·8
97	82·3	47	8·6
96	81·3	47	8·3
95	81·0	48	8·3
94	80·0	48	8·0
93	79·0	48	7·8
92	78·6	49	7·7
91	77·7	49	7·6
90	76·7	49	7·3
89	76·3	50	7·2
88	75·3	50	7·0
87	74·6	50	6·9
86	73·5	51	6·6
85	72·6	51	6·5
84	72·0	51	6·3
83	71·0	51	6·1
82	70·0	51	5·9
81	69·3	51	5·8
80	68·6	52	5·7
79	67·7	52	5·5
78	66·7	52	5·4
77	65·7	52	5·2
76	65·0	52	5·1
75	64·0	52	4·9
74	63·0	52	4·7
73	62·3	52	4·6
72	61·3	52	4·5

Dry bulb. °	Wet bulb. °	Relative humidity. Per cent.	Weight of vapour in grains.
71	61·0	53	4·4
70	60·0	53	4·3
69	59·0	53	4·1
68	58·3	53	4·1
67	57·3	53	3·9
66	56·3	53	3·8
65	55·5	53	3·7
64	54·5	53	3·5
63	53·7	54	3·4
62	53·0	54	3·4
61	52·0	54	3·2
60	51·0	54	3·1
59	50·3	54	3·1
58	49·3	54	3·0
57	48·3	54	2·8
56	47·5	54	2·7
55	46·7	55	2·6
54	46·0	55	2·6
53	45·0	55	2·5
52	44·3	55	2·5
51	43·5	56	2·4
50	42·5	56	2·3
49	41·7	56	2·2
48	41·0	57	2·2
47	40·2	57	2·1
46	39·2	57	2·0
45	38·4	57	2·0
44	37·8	58	2·0
43	36·8	58	1·9
42	35·6	58	1·8
41	35·0	58	1·7
40	34·2	58	1·6

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